A10738

TWR-5672

STUDY OF SOLID ROCKET MOTOR FOR SPACE SHUTTLE BOOSTER

VOLUME III PROGRAM ACQUISITION PLANNING

by

Thiokol / WASATCH DIVISION

A DIVISION OF THIOKOL CHEMICAL CORPORATION

prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

George C. Marshall Space Flight Center

Contract NAS 8-28430

Data Procurement Document No. 314

Data Requirement MA-02

THIS SPACE INTENTIONALLY LEFT BLANK

P.O. Box 524, Brigham City, Utah 84302
801/863-3511

Thiokol / WASATCH DIVISION

15 March 1972

National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

Attention: Mr. J. K. MacLean

Subject: NASA Contract Number NAS8-28430
Final Report

Gentlemen:

We are transmitting herewith the Final Report for The Study of A Solid Rocket Motor for Space Shuttle Booster pursuant to Article XIV, Reports Distribution, of the subject contract. The report comprises: Volume I, Executive Summary; Volume II, Technical (Books 1 thru 5, Appendices A thru H); Volume III, Program Planning Acquisition; and Volume IV, Cost.

Because of the size of the report and to expedite the submittal, we are transmitting three (3) of the 45 copies required by the contract designated for PD-RV. The remaining copies are being transmitted under separate cover.

Very truly yours,

J. Thirkill

John Thirkill
Project Manager
Space Shuttle Program

cc: A&TS-PR-RP/J.K. MacLean (1 cy)
A&TS-MS-IL (1 cy)
A&TS-TU (1 cy)
A&TS-MS-IP (2 cys)
PD-RV/Larry Wear (45 cys)

TWR-5672

FINAL REPORT

STUDY OF SOLID ROCKET MOTOR FOR SPACE SHUTTLE BOOSTER

VOLUME III PROGRAM ACQUISITION PLANNING

by

THIOKOL/WASATCH DIVISION
A Division of Thiokol Chemical Corporation
P.O. Box 524, Brigham City, Utah 84302

prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

15 March 1972

CONTRACT NAS 8-28430
Data Procurement Document No. 314
Data Requirement MA-02

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

Publications No. 0372-36176

PREFACE

This report contains the results of Thiokol Chemical Corporation's Study of Solid Rocket Motors for Space Shuttle Booster. The objective of the study was to provide data to assist National Aeronautics and Space Administration in selection of the booster for the Space Shuttle system. This objective was satisfied through definition of specific Solid Rocket Motor (SRM) stage designs, development program requirements, and production and launch program requirements, as well as the development of credible cost data for each program phase. The study was performed by Thiokol's Wasatch Division, Brigham City, Utah, for the NASA George C. Marshall Space Flight Center under Contract NAS 8-28430. The study was conducted under the direction of Mr. Daniel H. Driscoll/PD-RV-MGR NASA/MSFC. Thiokol study direction was provided by Messrs. E. R. Kearney, Corporate Director, Space Shuttle Program, and J. D. Thirkill, Program Manager, Space Shuttle SRM Booster Study, Wasatch Division.

The final report was prepared in response to Data Procurement Document 314 and Data Requirement MA-02. The report is arranged in four volumes:

Volume I - Executive Summary

Volume II - Technical

Volume III - Program Planning Acquisition

Volume IV - Cost

Data Requirement MA-02 specified that the Cost report be part of the Program Acquisition and Planning report but because of its importance and size it has been bound as a separate volume in this Final Report.

Volume II, Technical, has been further subdivided into five books as follows for ease of review and handling:

Book 1

Section 1.0 - Introduction
Section 2.0 - Propulsion System Definition
Section 3.0 - SRM Stage

Requests for further information should be directed to:

Thiokol Chemical Corporation
Wasatch Division
P. O. Box 524
Brigham City, Utah 84302

J. D. Thirkill 801 - 863-3511, Ext 3-3481

I. C. Adams 801 - 863-3511, Ext 3-3406

CONTENTS

CONTENTS (Cont)

CONTENTS (Cont)

CONTENTS (Cont)

CONTENTS (Cont)

CONTENTS (Cont)

CONTENTS (Cont)

CONTENTS (Cont)

ILLUSTRATIONS

ILLUSTRATIONS (Cont)

ILLUSTRATIONS (Cont)

LIST OF TABLES

LIST OF TABLES (Cont)

LIST OF TABLES (Cont)

1.0 INTRODUCTION

This volume, Program Acquisition Planning, of the Final Report, Study of Solid Rocket Motor for Space Shuttle Booster, was prepared to document the planning for the Space Shuttle Solid Rocket Motor Stage follow-on effort. This planning encompasses all aspects of the follow-on effort for development, flight testing, and production of a Solid Rocket Motor (SRM) Stage for the Space Shuttle.

Several configurations for the SRM Stage were studied under this contract and each of these are identified and discussed in detail in Volume II, Technical.

Since acquisition planning is not constrained by actual SRM Stage configuration, only one configuration is discussed in this volume.

Specifically, only the 156-in. diameter parallel burn configuration with thrust vector control and thrust termination is discussed in this volume. The planning of any other SRM Stage configuration can be developed from this report with relatively minor changes. The only significant changes occur in the program costs and these are discussed in detail in Volume IV, Costs.

2.0 PROGRAM PLAN

This program plan outlines the Thiokol Chemical Corporation plan for conducting the Verification and Production programs for the Solid Rocket Motor (SRM) Stage for the Space Shuttle. This program plan delineates the effort to be performed in demonstrating the capability of the Thiokol Wasatch Division, and its chosen subcontractors, to design and fabricate Solid Rocket Motor Stages which (1) conform to the NASA design requirements and (2) meet operational requirements of the Space Shuttle system.

This program plan also defines the scope of planned effort by project and task, and shows the relationship between program elements.

The program consists of components design and verification testing, full scale motor design, five verification motor and five Preliminary Flight Rating Motor Tests (PFRT), delivery of six flight test and two ground test stages, delivery of 440 production SRM Stages, and the management and support effort required. All data, reports, test plans, and documentation required for the program will be submitted in accordance with contractual requirements.

This program plan outlines in summary form the Thiokol plans and methods for accomplishing program direction and design, verification, PFRT, flight test, ground test, and production programs. The work breakdown structure for the verification and production programs follows.

WORK BREAKDOWN STRUCTURE
VERIFICATION AND PRODUCTION PROGRAM

Project	Task	Title
1.0		PROGRAM MANAGEMENT
		Program Management
		Contracts Administration
		Financial Control
		Procurement
		Safety
		Publications
2.0		SYSTEM ENGINEERING
		Project Engineering
		Systems Engineering
		Reliability
		Configuration Management
		Maintenance Engineering
		Mass Properties Control

THIS SPACE INTENTIONALLY LEFT BLANK

Project	Task	Title
3.0		SOLID ROCKET MOTORS
	3.1	CASE
	3.2	INSULATION
	3.3	PROPELLANT AND LINER
	3.4	NOZZLE, FLEXIBLE BEARING
	3.5	IGNITER
	3.6	THRUST VECTOR CONTROL
	3.7	THRUST TERMINATION
	3.8	POWER, ELECTRICAL, AVIONICS
		Malfunction Detection System
		Flight Instrumentation
		Cabling
	3.9	INTEGRATION, INSTALLATION, ASSEMBLY AND CHECKOUT
	3.10	GROUND TEST
		Verification Motor Testing
		PFRT Motor Testing
		Motor Post-Test Analysis and Storage
		Ground Test System Testing
		Production Process Control Testing
4.0		INTERSTAGE STRUCTURES
	4.1	STRUTS, THRUST AND SWAY
	4.2	NOSE FAIRING
	4.3	AFT SKIRT
5.0		FACILITIES
6.0		TOOLING
7.0		SUPPORT EQUIPMENT AND SPARES
	7.1	AIRBORNE VEHICLE SPARES
	7.2	GROUND SUPPORT EQUIPMENT
	7.3	GROUND SUPPORT EQUIPMENT SPARES
8.0		FLIGHT TEST SUPPORT
9.0		OPERATIONS SUPPORT
	9.1	THIOKOL OPERATIONS SUPPORT
	9.2	LAUNCH SITE OPERATIONS SUPPORT

Project	Task	Title
10.0		DATA
	10.1	MANAGEMENT DATA
	10.2	ENGINEERING DATA
	10.3	TECHNICAL ORDERS AND MANUALS
20.0		RAW MATERIALS AND COMPONENT PROCUREMENT
		OPTIONS
4.0	4.4	RECOVERY SYSTEM

Thiokol has used the following philosophy in preparing this program plan.

1. The meeting of program schedules, particularly the motor verification and PFRT testing requirements and the delivery of Ground Test Hardware (GTH), Flight Test Hardware (FTH) and production stages is of prime importance.

2. Tooling required for support of the production program must be acquired and validated during the qualification program.

3. The number of tests, hardware, and effort denoted in each subtask are for planning purposes only. The necessary tests, hardware, and effort will be conducted to achieve contractual verification and production requirements.

Thiokol plans to design and build the motors and components to NASA specifications. From the NASA specifications, Thiokol will develop detailed design drawings and specifications delineating the Thiokol Solid Rocket Motor Stage.

A master program schedule (Figure 2-1) and a verification motor test matrix (Table 2-1) are included as part of this program plan. They have been placed at the end of the volume and arranged as foldout pages to facilitate perusal concurrently with reading of the test. A view of the SRM Stage, showing major components and dimensions, is presented in Appendix D (TUL-13493).

2.1 PROGRAM MANAGEMENT (PROJECT 1.0)

The program management project encompasses the following functions.

1. Program Management

2. Contracts Administration

3. Financial Control

4. Procurement

5. Safety

6. Publications

Each of the functions is described in the following paragraphs.

2.1.1 Program Management

Thiokol will provide the necessary personnel, materials, and services to establish a Program Management Organization for conducting the Space Shuttle SRM Stage design, verification, PFRT, GTH, FTH, and Production Programs.

Organizational policy at the Wasatch Division provides that the Director, Program Management, has the responsibility and authority for the overall management, direction, and control of both contractually authorized programs and company-sponsored research and development programs. This responsibility and authority is subject only to the direction of the General Manager and/or the customer's contractual requirements.

It is also Division policy that the Director, Program Management, assigns a qualified program manager to each program who acts on behalf of the director on his assigned program. The program manager is responsible for the effective management of his assigned program and is accountable for successful accomplishment of the program's contractual specifications, direct costs, schedules, and other program requirements. The assigned program manager is the principal interface and spokesman with the customer on all program matters. As such, he establishes and defines all program policy and technical policy subject only to direction of the Director, Program Management, and/or the General Manager.

The program manager is supported by the members of a program team appointed by the directors of functional organizations performing work on a program within the Division. When serving as a program team member, an individual acts with the authority of his respective director on program matters.

The program manager is responsible for the successful completion of the overall program. Members of the program team are required to bring to the attention of the program manager deficiencies in work definition, program scheduling, and technical matters to assure that problems are corrected.

The program team members are responsible to the program manager's direction and support him fully in carrying out his assigned responsibilities. Further, they are responsible for implementing their assignments in accordance with management policy.

Figure 2-2 shows the organizational relationship of the program team through the Space Shuttle Program Manager and the Director, Program Management to the Vice President and General Manager of the Wasatch Division.

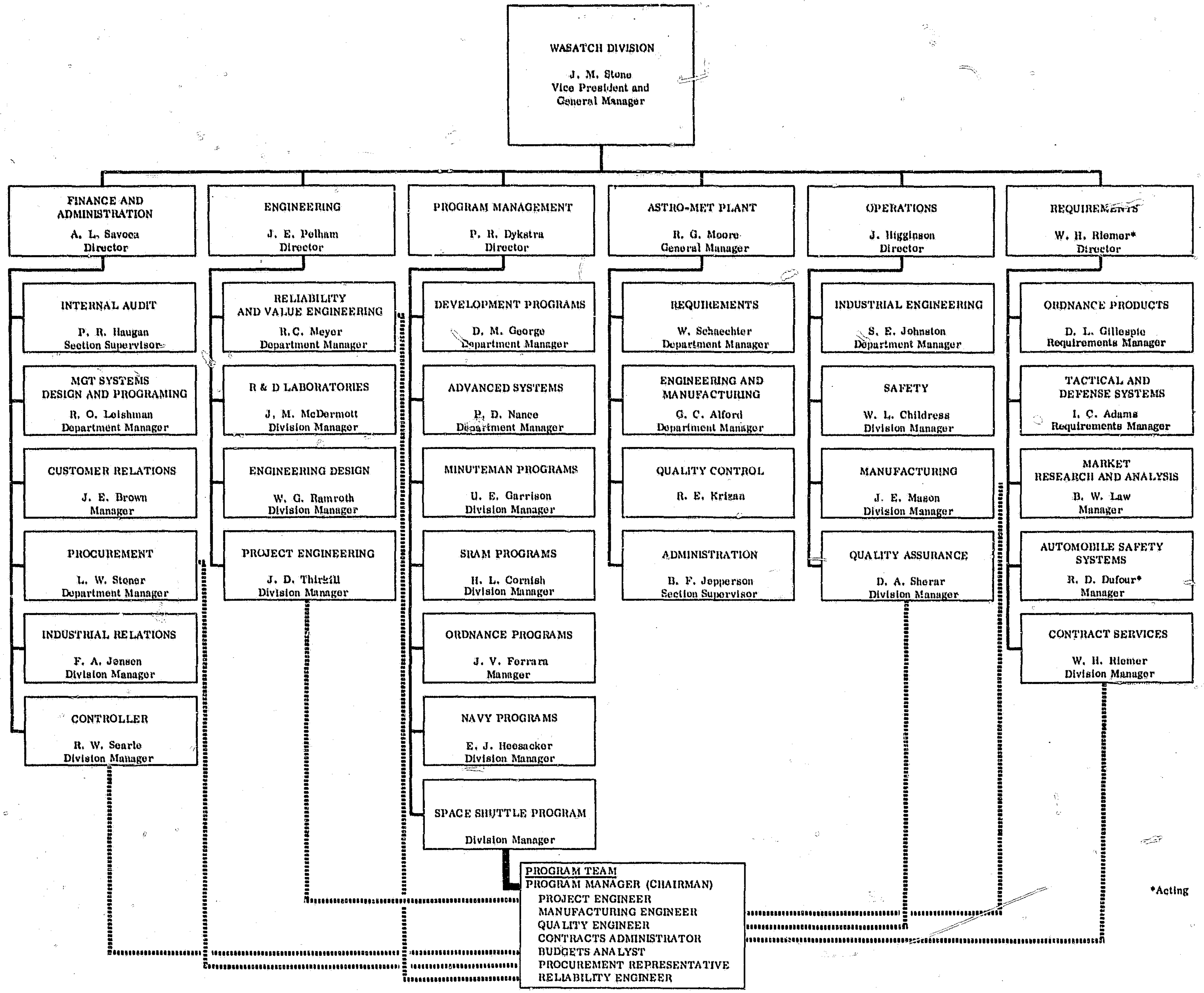
Figure 2-3 shows the detailed breakdown of responsibility within Program Management. The organization shown provides for rapid response to customer directions, efficient dissemination of information within Thiokol, and rapid feedback to the customer on all aspects of the Space Shuttle Program.

Program management responsibility includes direction of subcontractor and vendor efforts. The techniques and methods used for vendor control have been developed for use on Air Force programs and meet all current Air Force requirements. It is expected that these vendor control methods will meet NASA requirements with minimum modification. The requirements for data and reporting will be imposed on the subcontractors in the same manner as currently is used for Air Force programs.

A program control room will be established for the Space Shuttle program. Incorporated in this room will be status charts of each task and subtask that reflect progress against milestones. The data portrayed will include technical, schedule, and cost information, and will be organized to present results in a graphic form. This control room will be used as a primary source of data for management decision making, and will provide information required to prepare applicable reports.

Milestone reports will be prepared for the items identified as schedule critical items on the program. Milestone report data will be furnished as part of the NASA program meetings, and copies of the milestone charts will be maintained in the program control room for use by the Program Management Organization to aid in direction and control of the program.

The Space Shuttle manager and his staff will be responsible for maintaining liaison with the NASA, the Orbiter contractor, and other organizations as directed



2-4

Figure 2.2. Thiokol/Wasatch Division Organization Showing Program Management and Program Team Relationship

DIRECTOR
PROGRAM MANAGEMENT

MANAGER

Systems Engineering
Product Assurance
Ground Support Equipment
Logistics

MANAGER

Flexible Bearing Nozzle
Auxiliary Power Unit

MANAGER

Launch Site Operations

SPACE SHUTTLE PROGRAM
Division Manager

MANAGER

Integration Design
Configuration Management
Motor Manufacturing
Motor Static Test
Ground Test Hardware Program
Flight Test Hardware Program

MANAGER

Ordnance Systems
Ignition System
Power Supply & Distribution System
Flight Instrumentation
Malfunction Detection System

SPACE SHUTTLE PROGRAM
Assistant Division Manager

MANAGER

Motor Case
Nose Fairing
Aft Fairing
Interstage Structure
Recovery System

MANAGER

Budgets
Master Planning
Reports

MANAGER

Propellant
Liner
Insulation

Figure 2-3. Space Shuttle Program Management Organization

by NASA. This liaison will provide timely receipt and transmittal of pertinent information, and will be directed toward successful completion of the program and integration of the Thiokol furnished Solid Rocket Motor Stage into the Space Shuttle system. Thiokol will place particular emphasis on the direction and control of the Ground Test and Flight Test Programs to assure smooth integration of the Thiokol built SRM Stage into the flight and ground test Space Shuttle vehicles at the operational site. This effort, in turn, will lead to a smooth integration of the production SRM Stages into the operational Space Shuttle.

Thiokol will conduct or participate in the Program Technical Direction and Technical Interchange Meetings as required. Thiokol will provide formal presentation of program progress and review of the technical and schedule status, test results, and achievement of objectives. Printed copies of the charts and data presented by Thiokol at the TD meetings will be furnished to all attendees.

Thiokol will initiate and support Technical Interchange or Interface Control Meetings with the Orbiter contractor to permit smooth integration of the Thiokol produced Solid Rocket Motor Stage into the Space Shuttle.

Thiokol will maintain a system of vendor TD meetings to provide timely direction and control of the major subcontractors. NASA Program Office personnel will be invited to attend the scheduled vendor meetings.

Thiokol will implement and maintain a Management Information System based on contractual requirements. The system will provide reporting on cost and schedule performance in accordance with the provisions of the contract.

Thiokol will revise and update the Program Plan as required by changes in program direction or performance. The revisions and changes will be provided in looseleaf format so copies of the Program Plan can be kept up to date and used as working documents. Work release and cost collection on this program will be in accordance with the task breakdown of the Program Plan.

Program schedules will be prepared as required for direction and control of the program. Detailed schedules of component design, fabrication and delivery, tooling fabrication, motor manufacturing, motor final assembly and test, and stage delivery will be prepared and kept up to date.

2.1.2 Contracts Administration

Thiokol will provide the necessary personnel, materials, facilities and services to establish a contracts administration staff for conducting the Space Shuttle SRM Stage design, verification, PFRT, GTH, FTH, and production programs.

The Contracts Administration Organization will be responsible for conduct of all contract negotiations, processing of all contract changes and submittal of all contractually required programmatic data. In addition, contracts administration will be responsible to the Program Manager for interpretation of all contract requirements.

2.1.3 Financial Control

Thiokol will provide the necessary personnel, materials, facilities, and services to establish a financial control staff for conducting the Space Shuttle SRM Stage design, verification, PFRT, GTH, FTH and Production Programs.

Financial control will be responsible for auditing of all program Management Cost and Control System (MCCS) Planning Charts and inputting to the MCCS system for Time Plan, Baseline Budget, and Initial Estimate at Completion; maintaining Budget Logs; distributing and inputting Status Completion Reports; generating and distributing weekly/monthly cost reports including labor monitor, Variance Analysis Reports, Program Status Reports, and special cost reports; coordinating and establishing value of material packages at part number level for development of the material budget; reporting and monitoring all material Planned Value Work Accomplished utilizing the present component and raw material inventory system; coordinating and maintaining material cost planning indicators; Material Variance Analysis and other special analyses as required; preparing internal and customer reports on an "as required" basis.

2.1.4 Procurement

Thiokol will provide the necessary personnel, materials, facilities, and services to establish a procurement staff for conducting the Space Shuttle SRM Stage design, verification, PFRT, GTH, FTH, and Production Programs.

Thiokol's Procurement Department reports directly to the Director of Finance and Administration, who in turn reports directly to the Vice President and General Manager (Figure 2-4). All procurement actions contemplated in a given program are approved at this level without further endorsement by the Thiokol Corporate Office. To obtain maximum buyer efficiency and a thorough knowledge of products in a rapidly changing environment, the buying groups are organized on a commodity basis--end items of a similar nature are procured by a specific buyer with the greatest applicable knowledge of that end item. The two buying groups are Production Purchasing and Supply Purchasing.

All requisitions requiring procurement of items in these general classifications are assigned to the group responsible for these end items. Further commodity breakdown at the buyer level is accomplished, particularly in the Production Purchasing Section. Thus, such complex items as cases, nozzles, raw materials, insulation, etc., are always procured by the same buyer. In effect, specialists may devote their buying talents to a specific family of items rather than dilute their buying specialties by procuring on a program basis.

In addition to the buying groups enumerated, the Administrative Group provides full time cost and price analysis, Integrated Data Transmission (IDT) typing service, and similar support to the buying groups. Additional functions

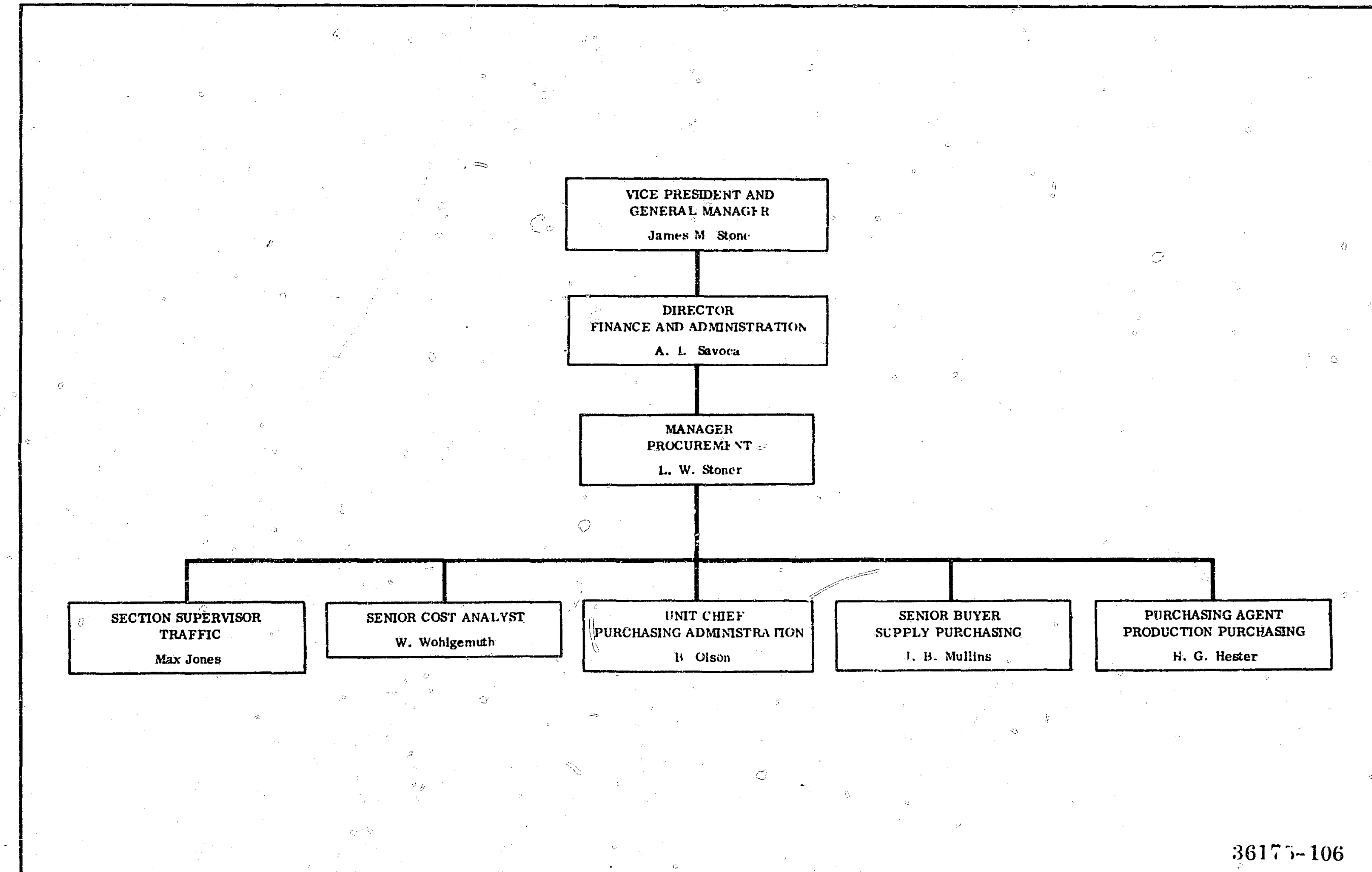


Figure 2-4. Procurement Organizational Chart

performed by the Administrative Group are in the area of source selection and vendor evaluation. Thiokol's vendor rating system has received national publicity in The Purchasing Magazine.

Because of the close relationship between Procurement and Traffic, the latter organization is assigned to the Procurement Department. All matters relating to the movement of goods, either by commercial or Government Bill of Lading, are the responsibility of the Traffic Supervisor. A close, day-to-day relationship exists between Traffic and Procurement, not only to expedite shipments and similar classical traffic functions, but also to assure that procurements are placed giving due regard to overall price including traffic costs.

The Wasatch Division procurement system was reapproved by the Contracting Officer, upon recommendation from the Air Force Western Procurement Management Region, on 30 September 1970. The system responds to procurement requirements imposed in contracts with the Army, Navy, Air Force, Atomic Energy Commission, and several prime contractors responding to these agencies. A full time Air Force Procurement Methods Analyst is in residence in the Procurement Department. In addition, the procurement system is audited annually by Thiokol Internal Auditors and by the Arthur Young and Company, Certified Public Accountants.

Thiokol Corporate policy favors the competition of qualified businesses listed with the Small Business Administration. Small businesses and those businesses located in labor surplus areas will be given equitable opportunity to compete for available contracts. During recent surveys, team members representing the Small Business Administration have been most complimentary about Thiokol's program and practices.

The Thiokol vendor control plan, a primary part of the procurement system, has three main objectives: (1) configuration management in accordance with contract requirements, (2) cost control, and (3) schedule control and visibility.

Contractor selection and award is based upon a continuously updated approved listing of sources that identified contractors regarded by Thiokol as qualified to supply specific products and services. A contractor evaluation system is used to rate potential suppliers on a quality and delivery basis determined by (1) Thiokol team surveys of supplier plants, (2) facilities questionnaire surveys, and (3) actual performance evaluation. In addition, for those procurements anticipated to be in excess of $500,000, a Procurement Review Board, chaired by the Manager of Procurement, is convened to evaluate and make source selections. Membership on this board consists of the Managers or Directors of Finance and Administration, Engineering, Quality Assurance, Program Management, Contract Services, and Operations, plus other technical personnel who may have a direct interest in procurement. In the matter of source selection for a specific program, Thiokol has demonstrated a capability to work with sources approved by means other than the system enumerated above.

2.1.5 Safety

Thiokol will provide the personnel and services necessary to conduct a safety program in support of the Space Shuttle SRM Stage design, verification, PFRT, GTH, FTH and Production Programs. This function includes the planning and administration, surveillance, and system safety engineering effort required to conduct a system safety engineering program as specified by NASA.

The safety program will be prepared in the form of a System Safety Plan (SSP), and submitted for NASA approval before incorporation into the contract. Safety functional analyses will be conducted on all new materials, parts, components and radiographic inspection to determine safety criteria, and to develop procedures and directives for personnel engaged in handling, fabrication, and testing.

Participation in the Space Shuttle Safety Program will be as defined by NASA. Attendance at Safety Technical Interchange Meetings and support of safety working groups at system test sites, as specified, will also be provided.

Preparation and submittal of status reports, range safety data inputs to the launch site, and other data and reports not listed elsewhere will be provided as required.

Thiokol has developed procedures, techniques, and safety criteria for physical safety inspection and training. These procedures will be reviewed and revised for acceptability and applicability to the Space Shuttle program. Surveys for safety oriented factors, plus requisite surveillance and testing, will be conducted to establish new procedures, techniques, and safety criteria to fulfill Space Shuttle program requirements.

Specific safety requirements for all items or services purchased from vendors and subcontractors will be established. All purchased items and services will be obtained on procurement documents which are reviewed to assure incorporation of safety requirements. Verification of compliance will be assured by a comprehensive program for spot check and surveillance of operations.

Hazard classifications for storage, handling, and shipping will be identified for all explosive ordnance in accordance with NASA requirements. The hazard classification for each item or component will be obtained from the Department of Transportation (ICC), and the military hazard classification will be recommended. In compliance with contract requirements, Thiokol will submit an Explosive Component Technical Data Package for each explosive item or component which does not have a hazard classification listed in the Federal Catalog.

The Safety Program will provide development of ordnance technical data as specified by NASA. Data cards for explosive items will be prepared, as required

by the item detail specification. Lot acceptance firing data, such as time and pressure charts, for explosive items will be reported in accordance with NASA requirements.

Explosive ordnance items will be color coded in accordance with NASA requirements. Marking, handling, storage, and transportation of explosive ordnance items will be in accordance with NASA requirements and Department of Transportation regulations.

2.1.6 Publications

Thiokol will provide the necessary personnel, materials, facilities, and services to establish a Publications Organization in support of the Space Shuttle SRM Stage design, verification, PFRT, GTH, FTH and Production Programs.

The Publications Organization will be responsible for preparation of all technical manuals and technical orders, for editing, illustrating, compositing, quality assurance, printing, and binding all contractually required reports and for providing reproduction services throughout the plant to reproduce engineering drawings and specifications, manufacturing shop travelers, quality control inspection sheets, safety requirements sheets, and any other program miscellaneous data.

2.2 SYSTEM ENGINEERING (PROJECT 2.0)

The system engineering project encompasses the following functions as described in the following paragraphs.

1. Project Engineering
2. System Engineering
3. Reliability
4. Configuration Management
5. Maintenance Engineering
6. Mass Properties Control

2.2.1 Project Engineering

Thiokol will provide the necessary personnel, materials, facilities, and services to establish a Project Engineering Organization for conducting the Space Shuttle SRM Stage design, Verification, PFRT, GTH, FTH, and Production Programs. This Project Engineering Organization will be responsible for planning and scheduling the technical effort to assure compliance with program technical and schedule requirements.

The Project Engineering Organization will interpret customer and Thiokol internal requirements and direct the incorporation of these requirements into the Systems Requirements Analysis and appropriate Engineering Specifications and Drawings.

Project Engineering will plan, budget, coordinate, and monitor all technical effort on the program. This will include preparation of Engineering Work Orders defining specific tasks to be performed, specific performing organization, and detailed budget for accomplishment of the work effort.

Project Engineering will approve all engineering effort by signing all technical data such as specifications, drawings, technical reports, etc, prior to release to other organizations within Thiokol and prior to submittal to NASA.

Project Engineering will be the official technical representative of Thiokol at all program meetings with NASA and with vendors.

2.2.2 System Engineering

Thiokol will provide the necessary personnel, materials, and service to conduct a Systems Engineering Analysis for developing the Space Shuttle SRM Stage design requirements baseline and product configuration baseline, and the Ground Support Equipment (GSE), facilities, personnel, and procedural data required for the launch site.

System engineering is the orderly definition of system baselines and baseline changes through the use of uniform documentation, engineering reviews, and standard procedures. System engineering leads to an orderly development of the program requirements baseline, the design requirement baseline, and the product configuration baseline. A constant iteration of the analyses will be conducted to assure that, as the design becomes more definitive, the control becomes more restrictive. Constant iterations assure that the design effort is constrained to comply with identified system requirements.

System engineering will be conducted to satisfy the following specific objectives.

1. Define airborne hardware, ground support equipment, facilities, personnel, and procedural data that are required to fulfill system requirements, thus eliminating the possibility of overlooking these details.

2. Develop performance, design, and quality assurance requirements during early design on the basis of the integration and tradeoff of system performance requirements, system elements and system and end item design constraints.

3. Interrelate the system engineering and design effort in the development of equipment requirements, facility requirements, checkout and assembly philosophy, transportation and handling philosophy, personnel requirements, training requirements, test requirements, procedural data requirements, etc.

4. Verify the compatibility between all elements of the SRM Stage and those of other contractors or agencies through study of the functional analysis data developed by other contractors.

5. Define the intersystem and intrasystem interfaces of each step throughout the definition and acquisition processes.

6. Provide all necessary information and/or known problem areas to NASA for the resolution of unresolved problems.

7. Develop source data for determining training requirements such as: training courses, training equipment, etc.

8. Develop source data for determining logistic requirements needed to support the SRM Stage.

9. Develop source data for deriving operating and mainteance procedures for the SRM Stage.

10. Establish documentation which will provide for clear and concise communication of requirements between NASA and Thiokol and between Thiokol and other contractors.

11. Provide the technical basis for configuration management activities such as: the definition and justification of program requirements: the establishment of the program requirements baseline, design requirements baseline, and product configuration baseline and development of specifications.

The system engineering process provides the control and documents the design constraints and requirements used by the design engineers in the development of the contract end item overall requirements. The system engineering process will be used to control and document the decisions and constraints of the following disciplines.

1. Maintainability: Overall system maintainability requirements will be documented including human factors which are involved in each maintenance operation. Human limitation, minimum time to accomplish maintenance tasks, and the use of the lowest possible level of skills is of prime consideration. The maintainability requirements will be included as a part of the System Engineering Documentation.

2. Safety: Safety requirements will be documented in the Systems Analysis. Safety will be given prime consideration in the evaluation of factors involved in tradeoffs, and special studies related to handling, transportation, storage, assembly, checkout, etc.

3. Reliability: The results of reliability studies and reliability requirements will be documented in the Systems Analysis.

4. Logistics: Types of personnel, equipment, and facilities for the system will be developed and included as a part of the system engineering development and documentation. Special consideration will be given to the personnel, equipment, and facilities that are available and have been used in previous programs.

Thiokol has developed a systems engineering organizational structure and working procedures which lead to close working relationship between the systems engineers and all other engineering specialists. Thiokol has also developed effective channels of communication among all engineering disciplines including airborne equipment and ground support equipment design, logistics, safety, reliability, maintainability, etc, to assure their timely responses to and inputs into the system engineering effort.

System engineers prepare the system requirements analysis documentation with assistance from the support and design engineering organizations. Airborne equipment, ground support equipment, maintenance, facilities, personnel, and procedural data requirements are identified by system engineers. Associated design, specification, and manual preparation are performed by design engineers, specification engineers, and technical manual writers, respectively.

2.2.3 Reliability

Thiokol will provide the necessary personnel, materials, and services to conduct a reliability program in accordance with NASA reliability program requirements. This program will be an extension of the current reliability programs being conducted for the Air Force in accordance with MIL-STD-785A, Reliability Programs for Systems and Equipment Development and Production, and for the Navy in accordance with NAVWEPS OD 29304, Guide Manual for Reliability Measurement Program.

Thiokol will prepare and submit a Reliability Program Plan. The plan will include all reliability program elements required by NASA and will describe the integrated Thiokol effort in achieving a reliable SRM Stage for operational use. The work tasks assigned for the reliability program will be described in the Reliability Program Plan. These tasks will prescribe work effort procedures, and documents required by the specifications and Statement of Work. The tasks in general will be (1) reliability program planning and administration, (2) reliability requirements and prediction, (3) parts improvement, (4) supplier reliability control, (5) reliability indoctrination and training, (6) product assurance evaluation,

(7) process surveillance, (8) failure reporting and corrective action, and (9) reliability evaluation and demonstration.

The Reliability Program Plan will be written as a working document for implementation as a contractual document during the Verification and Production Programs. Quantitative requirement studies will be included to allocate requirements to component level. Methods for achieving requirements and implementing the controls will be included.

Interfaces of the working organizations and descriptions of implementation procedures will be provided in detail in the Reliability Program Plan. Requirements for supplier reliability requirements will be included. These will consist of provisions in major supplier purchase packages for a program plan, failure report system, process monitoring, and periodic reporting to Thiokol.

Numerical reliability requirements, specified by NASA for countdown and flight reliability requirements, will be used as the overall goal of the program.

Thiokol will conduct a Reliability Demonstration Program in accordance with NASA requirements. The total number of motors in the Verification Program is not sufficient to establish that motors are meeting formal reliability requirements. All motors after verification will be evaluated, and the results will be accumulated for continued reliability demonstration in the subsequent Production Program. The probability of motor failure will be assessed using variables type data because the number of applicable tests will be insufficient to provide a satisfactory measure of motor reliability on an attribute basis. The variables data accumulated for the 10 static fired verification and PFRT motors will provide the basis for a realistic appraisal of the SRM reliability at this phase of the program.

Thiokol will prepare and implement a Reliability Demonstration Plan in accordance with NASA requirements. This task will be completed using the communication channels, forms, and procedures identified by NASA.

Thiokol will schedule periodic program reviews to assess status, progress, and problems, as required by NASA, and will support specified reviews and working group meetings by supplying appropriate charts, graphs, and reliability data.

Thiokol will prepare and submit reports and documents in accordance with NASA requirements. These will include Reliability Pretest Declaration, Post-Test Reports, Reliability and Failure Reports, and Reliability Status Reports as required.

2.2.4 Configuration Management

Thiokol will provide the personnel, materials, and services needed to conduct a Configuration Management Program for the Space Shuttle Solid Rocket Motor Stage. This task includes the effort necessary to conduct a configuration

identification, control, and accounting program to assure configuration management and control of the SRM Stage. This program will be an extension of the configuration management program principles of MIL-STD-483 (USAF), Configuration Management Practices for Systems, Equipment, Munitions, and Computer Programs currently in effect on Air Force Programs.

The Configuration Management Program will include continued indoctrination of the employees, subcontractors, and vendors whose efforts are related to, and must interface with, configuration management. Configuration management will be imposed upon subcontractors and vendors by the use of the following Thiokol Standards.

1. TW-STD-123, Configuration Management, Chemical Raw Material Supplier.

2. TW-STD-124, Supplier Quality Assurance System, Chemical Raw Materials.

3. TW-STD-125, Configuration Management, Systems, Hardware, and Component Suppliers.

These Standards establish the minimum requirements for the supplier configuration management and quality assurance systems. They require that the supplier establish a configuration baseline before qualification of the product or material, and prohibit any change of material, manufacturing equipment, production, or process methods from the baseline configuration.

Thiokol will prepare a Configuration Management Plan that describes the implementation of contractual configuration management requirements of the Space Shuttle Program.

Thiokol will implement the configuration management identification requirements for Space Shuttle equipment, serialization, engineering drawings and associated drawing lists, nomenclature and nameplates, and descriptive identification data in accordance with applicable NASA requirements.

Thiokol will prepare and maintain a current indentured parts list defining the approved design configuration.

NASA and Thiokol end item serial numbers will be assigned to each Configuration Item (CI) in the initial stage of manufacture. All end item serialization will be in accordance with NASA requirements. Delivery of a CI for each Government serial number will not be required, and the delivery of completed CI's need not be by sequential Government serial numbers. A listing of requirements for lot numbering and serialization of materials, parts, and assemblies will be submitted to NASA for concurrence. The use of lot numbers and serialization will be controlled by drawing and specifications.

A nameplate or decal will be affixed to each CI, following satisfactory completion of acceptance tests. The nameplate or decal will include model numbers, serial numbers, and other data required by NASA.

Prior to Physical Configuration Audit (PCA), Thiokol will generate and maintain internal configuration identification records for all items. The records will be kept current by expanding, to cover the Space Shuttle Program, an existing computer configuration accounting system developed for the Minuteman Stage I internal configuration identification system.

Thiokol will participate in and support the Space Shuttle Interface and Space Control Program in accordance with NASA requirements.

Engineering Change Proposals (Class I or II) will be submitted only if they are considered mandatory to meet the requirements of the Space Shuttle Program. In the event that a change is required, the proposed change will be prepared in the proper format in accordance with NASA requirements. These proposed changes will be submitted to the designated NASA cognizant agency.

2.2.5 Maintenance Engineering

Thiokol will provide the necessary personnel, facilities, materials, and services to perform a thorough and complete Maintenance Engineering Analysis (MEA). The MEA will be conducted for each reparable contract end item to the lowest applicable level of repair. The analysis depth will be based on the maintenance philosophy and requirements of NASA and Thiokol. Most maintenance functions to be performed at the Kennedy Space Center (KSC) will be of the remove-install, inspect, and checkout nature, thus requiring a minimum support for maintenance at KSC.

Format and content of the MEA will be in accordance with the MEA requirements of NASA.

The MEA will be performed to identify the following:

1. All SRM system preventive maintenance functions required on a completely installed SRM Stage in its operational configuration and the supporting GSE.

2. All unscheduled maintenance functions which can be accomplished on equipment items in a system installed configuration to restore the system to an operational configuration.

3. All maintenance functions required on each reparable assembly which may be removed/installed in the system-installed configuration.

4. All maintenance functions required on each reparable assembly which may be removed/installed only after its higher assembly has been removed from the system installed configuration

The MEA will amplify each maintenance function identified in terms of:

1. Preventive maintenance functions and recommended frequency.

2. Unscheduled maintenance functions and the failure rate which leads to its frequency.

3. Equipment recommended to perform the maintenance function.

4. Location of maintenance function performance.

5. Personnel requirements in terms of type, time, and number of personnel.

6. Provisioning information for each indenture. This data will be used to plan spares quantities, types, and frequency.

7. Procedural and/or technical data required to support each maintenance function.

8. Facility requirements to perform each maintenance function.

9. Equipment calibration requirements.

Equipment design specifications will be prepared for each deliverable item of maintenance ground equipment identified by the MEA. The first section of the specification constitutes the design criteria extracted from the MEA. This criteria includes the functional requirements which are necessary and sufficient for reaching a contractual agreement with NASA prior to initiation of the detailed design. Maximum consideration will be given for selection of off-the-shelf commercial equipment currently available and equipment already available in the government inventory before any design of new equipment will be recommended.

A summary of calibration requirements for items of Maintenance Ground Equipment, Ground Support Equipment, and SRM Stage equipment will be prepared. This summary will be a tool to be used in evaluating existing, or establishing new, calibration standards based upon ground system operational and maintenance characteristics. It will include measurement requirements for all applicable equipment.

A time line analysis will be conducted to provide source data for technical evaluation of equipment and personnel reaction times and analysis and evaluation of support system characteristics. The analysis will be performed for operations involving time-critical functions. The time line analysis will provide data for determining the required quantities of maintenance ground equipment, personnel, spare parts, and to determine system downtimes for scheduled and unscheduled maintenance.

The MEA data approval will be obtained through NASA per procedures to be identified by NASA. Pending the approval indicated, Thiokol will use the data developed for controlling internal design efforts such as equipment design,

procurement, technical manual development, etc. Documentation changes not involving detailed design requirements, personnel and quantities will not require approval.

Analysis changes will be initiated in response to problems identified during preliminary design, design reviews, detailed design, engineering testing and follow-on test programs, technical manual reviews, spares provisioning, equipment procurement, and operational usage. Time lags will be eliminated by using working copies of the changes documentation. A working copy is defined as any revision technique that produces a readable, reproducible and controlled prototype of the final product. The objective is to provide control over detailed design efforts and timely distribution and utilization of MEA source data. Thiokol will maintain a timely and accurate system of control and distribution of MEA data for use by designers, technical manual writers, provisioning groups, etc. This system of control is analogous to that which is used for production drawings.

2.2.6 Mass Properties Control

Thiokol will provide the personnel, materials, facilities, and services necessary to establish a system of mass properties monitoring and control in accordance with MIL-M-38310A (USAF). In addition, this effort includes development and maintenance of mass properties objectives, and planning and execution of a mass properties control plan.

The implementation of this control plan will assure compliance with the mass properties requirements specified by NASA, and will assure that the required data are reported accurately and on time.

2.2.6.1 Monitoring and Control

The Space Shuttle mass properties requirements and objectives have been developed by NASA. The mass properties control program conducted by Thiokol will establish a system of mass properties monitoring, control, and maintenance of mass properties objectives using these developed requirements, in accordance with the requirements of MIL-M-38310A (USAF). Qualified personnel will develop the mass properties control and monitoring system and, will be responsible to assure that the specified mass properties objectives are attained.

2.2.6.2 Planning and Execution

The mass properties group will function as a central source for data acquisition, dissemination, review, and reporting. Mass properties personnel, working with scheduling and planning personnel, will delineate a system by which

the mass properties data, determined during the manufacturing cycle, will be submitted to the responsible mass properties engineer for review to assure that program objectives are not impaired. The data will be in the form of an inhouse control standard. If, during the course of data review, an adverse trend that could impair program objectives is indicated, the mass properties engineer will be responsible to notify the project office so that corrective action can be initiated.

In conjunction with these responsibilities, the mass properties engineer also will monitor data developed by subcontractors. The contractor mass properties personnel will assist subcontractor personnel in developing a plan which will assure accurate and timely data reporting, and a means by which adverse trends can be detected and corrective action initiated.

2.2.6.3 Mass Properties Reporting

Mass properties reports will be developed during the verification and production program in consonance with the requirements of MIL-M-38310. These reports will be disseminated in accordance with the Data Procurement Document requirements.

2.3 SOLID ROCKET MOTORS (PROJECT 3.0)

Under this project Thiokol will provide the personnel, services, materials, and facilities necessary to perform the design, receiving inspection, component qualification, rocket motor manufacturing, and testing of the verification and PFRT motors and the manufacturing, delivery, and erection of the Solid Rocket Motor Stages for GTH, FTH, and Production Programs. Component design and qualification, rocket motor design and manufacturing, verification motor and PFRT motor testing, and GTH, FTH, and Production Manufacturing, delivery, and erection are discussed in detail in the following paragraphs.

2.3.1 Case (Task 3.1)

Under this task, Thiokol will provide the personnel, services, materials, and facilities necessary to perform the design, receiving inspection, and qualification testing of the solid rocket motor case. The receiving inspection and case preparation up to insulating the case will be performed for all cases for the verification, PFRT, GTH, FTH, and production programs.

2.3.1.1 Case Configuration

Thiokol will design a 156-in. diameter segmented steel case for use in the Solid Rocket Motor Booster for the Space Shuttle system. The case will be designed with a burst factor of safety of 1.4 MEOP using 200,000 psi minimum yield strength. The motor case will be fabricated to the NASA approved Thiokol design disclosure from D6AC steel. The case components will be procured from a vendor who has demonstrated his ability to produce high quality rocket motor cases from D6AC steel.

2.3.1.2 Qualification Program

Case qualification will be accomplished by receiving, inspecting, and hydroburst testing two case assemblies consisting of a forward segment, a center segment and an aft segment in each test.

In addition, forward and aft segments with integral skirts will be tested structurally as part of the interstage qualification testing described in Project 4.0. The case segments will be instrumented to measure structural loads and deformation while the interstage structures are being destructively tested.

2.3.1.3 Program Completion

Case qualification will be considered successfully accomplished when the forward and aft closures with integral skirts have demonstrated capability to withstand flight induced loads, the two hydroburst tests have demonstrated the

pressure integrity of the case design, and the verification and PFRT motor testing has been completed.

2.3.1.4 Program Cases

All rocket motor cases for use in the Space Shuttle Program will be proof tested by the vendor at a pressure equal to 1.2 times MEOP prior to being shipped to Thiokol. Cases for the motor verification, PFRT, GTH, FTH, and production programs will be received by Thiokol, inspected, and prepared for insulation under this task.

2.3.2 Internal Insulation Qualification (Task 3.2)

Under this task, Thiokol will provide the personnel, services, materials, and facilities necessary to perform the design, fabrication, assembly, and qualification testing of internal insulation. In addition, Thiokol will fabricate insulation for all motors in the development, PFRT, GTH, FTH, and production motor programs.

2.3.2.1 System Configuration

The internal insulation components will be designed to provide protection to the metal case throughout motor action time. An appropriate factor of safety commensurate with manrating requirements will be applied. The internal insulation will be fabricated from asbestos-silica filled NBR to the NASA approved Thiokol design disclosure. The internal insulation components include the segment wall insulators and the propellant stress relief flaps.

2.3.2.2 Qualification Testing

The internal insulation qualification program will be conducted in three phases.

Phase I--Laboratory tests will be conducted in accordance with the Thiokol Material Specifications to determine the physical and chemical properties and insulating characteristics of candidate asbestos-silica filled NBR insulation materials.

Phase II--Four candidate insulation materials will be tested further in accordance with the matrix shown on Table 2-2. These tests will be designed to evaluate the bonding characteristics of the liner-insulation combinations. All testing will be performed in accordance with the master schedule. Only the most promising candidates will be used in Phase III.

Phase III--In this final phase of the program Thiokol will conduct the specific

TABLE 2-2

TESTING MATRIX FOR ALTERNATE SOURCE INSULATION MATERIALS

Four Candidate Insulation Materials	No. 1			No. 2			No. 3			No. 4		
Characterize Bond to Propellant												
Liner Thickness	None	0.045	0.065	None	0.045	0.065	None	0.045	0.065	None	0.045	0.065
Tests and No. of Specimens												
Propellant Adhesion Cup	3	5	3	3	5	3	3	5	3	3	5	3
180 Deg Peel	3	5	3	3	5	3	3	5	3	3	5	3
Characterize Bond to Case												
Tests and No. of Specimens												
Adhesion Disc	--	3	--	--	3	--	--	3	--	--	3	--
180 Deg Peel	--	3	--	--	3	--	--	3	--	--	3	--

tests and quantities defined in Table 2-3 to demonstrate and verify the following.

1. Component Fabrication Verification--The insulator manufacturing tooling procedures and processes result in insulation material that will properly bond to the D6AC steel case and to the liner.

2. System Bond Strength Verification--Thiokol's capability to produce and process insulation meeting all requirements of the individual materials specifications, and the composite system (case, insulation, liner, propellant) bond strength requirements in the SRM specification. The specific tests and quantities are defined in Table 2-3.

To assure that the data from the sample testing will be representative of the full scale motors, liner and propellant used for these samples will be taken from full scale mixes prepared during the initial liner and propellant standardization.

These composite test specimens will be prepared from materials which have been subjected to the same environment they will experience during normal motor processing. The insulation material will be cured in the same manner and for the same time-temperature history as the motor insulator would experience. After removal of the molding tooling, the insulation specimen will be prepared for liner application using the same process as specified for the motor. Liner will be applied and cured for the prescribed time-temperature history. Propellant will be cast and cured using the motor time-temperature specifications.

Composite test specimens will be prepared in accordance with NASA approved Thiokol specifications.

The candidate alternate source insulation materials successfully passing all of the tests defined will be utilized to fabricate a minimum of two of each configuration of insulators for use in the verification motor program. Post-test examination of each insulator used in the verification motor program will be accomplished to discern any differences among the candidate materials. Each candidate material will be examined in detail to determine insulation characteristics in actual motor testing. Candidates considered adequate for motor use will be further tested in the PFRT motor test program. All candidate materials which successfully pass verification and PFRT motor testing will be considered as acceptable alternate materials for use in the production program. All insulator fabrication tooling, processes, and procedures for use in the production program will be developed and demonstrated during the verification and PFRT motor program.

TABLE 2-3

TESTING MATRIX TO DEMONSTRATE INSULATION SYSTEM FABRICATION CAPABILITY

Insulation Material	Candidate X			Candidate Y		
Liner Thickness (in.)	None	0.045	0.065	None	0.045	0.065
Propellant	X	X	X	X	X	X
Test and No. of Specimens						
Double Plate Tensile	3	5	3	3	5	3
Double Plate Shear	3	5	3	3	5	3
90 Deg Peel	3	5	3	3	5	3

2.3.2.3 Qualification Test Completion

The internal insulation qualification will be considered complete when the laboratory testing and inspection of insulators and materials demonstrate that they meet specification requirements. Final qualification of the system will be complete at the end of the PFRT motor testing program.

2.3.2.4 Program Insulation

Insulation materials for the GTH, FTH, and production programs will be received and inspected by Thiokol using the specification developed during the insulation qualification program. In addition, insulators for these programs will be fabricated using the tooling, processes and procedures developed and demonstrated during the verification and PFRT motor programs.

2.3.3 Propellant and Liner Demonstration (Task 3.3)

Under this task, Thiokol will provide the personnel, materials, services, equipment, and facilities necessary to demonstrate that the propellant and liner produced by Thiokol for the Space Shuttle Solid Rocket Motor will meet the requirements of the Space Shuttle Program. In addition, personnel, materials, services, equipment, and facilities will be provided to line and cast all motors for the verification, PFRT, GTH, FTH, and production motor programs.

2.3.3.1 Configuration

Thiokol will produce TP-H1011 propellant and UF-1121 liner in accordance with the inprocess, ballistic, and mechanical properties requirements specified in the NASA approved Thiokol design disclosure. Raw materials will be procured from Minuteman qualified vendors and will be manufactured to the Space Shuttle specifications.

2.3.3.2 Verification Testing

Thiokol will make two full size mixes of TP-H1011 propellant to evaluate variation of oxidizer grind ratios. Ballistic and physical property data will be determined from nine 5-in. diameter center perforate (CP) motors, 27 uncured strands and nine 1/2 gal loaf samples from each mix. Normal QC data will be taken.

Thiokol will make two full scale mixes of liner from which physical property data will be determined to show that the liner meets specification requirements.

From the above mixes of propellant and liner, the required number of samples will be prepared in accordance with Task 3.2, above, to support the demonstration of the insulation, liner, propellant bonding system. All propellant

and liner specifications, processes, and procedures required for use in the motor program will be developed and submitted to NASA for approval.

2.3.3.3 Verification Completion

The propellant and liner verification program will be considered complete when the following is accomplished.

1. The test motors manufactured during standardization demonstrate ballistic performance that meets the requirements of the Thiokol design disclosure.

2. Laboratory tests demonstrate that the propellant and liner meet the physical property requirements of the Thiokol design disclosure.

Final qualification will be complete at the completion of the PFRT Program.

2.3.3.4 Program Propellant and Liner

All propellant and liner materials will be received, inspected, and accepted in accordance with the approved specification developed above. All propellant and liner for use in the verification, PFRT, GTH, FTH, and production motor programs will be manufactured under this task using the NASA approved specifications.

2.3.4 Flexible Bearing Nozzle Demonstration (Task 3.4)

Under this task Thiokol will provide the personnel, services, materials. and facilities necessary to perform the design, fabrication, assembly and qualification testing of the flexible bearing movable nozzle. In addition all nozzles for the motor verification, PFRT, GTH, FTH, and production programs will be received and inspected under this task.

2.3.4.1 System Configuration

The Solid Rocket Motor nozzle will be movable submerged design with a flexible seal bearing providing omniaxial movement capability. Forged steel components form the primary structure, and provide for motor and flexible seal bearing attachment. The nozzle structural elements are covered with ablative materials, which protect and insulate the metallic elements and the flexible seal bearing and form the nozzle flow contours. An ablative nozzle throat will be used.

The nozzle will be procured from a technically approved nozzle fabricator. The nozzles will be fabricated in accordance with the requirements of the NASA approved Thiokol design disclosure. The flexible bearing seals will be fabricated by Thiokol and provided to the selected nozzle vendor. Types of materials and material performance requirements rather than specific materials and sources will be required by the design disclosure documents. The materials used by the nozzle vendor must meet the requirements of the applicable specifications before approval for use.

2.3.4.2 Verification Program

The following environmental and functional tests will be performed on nozzle materials, parts, and assemblies.

2.3.4.2.1 Ablative and Insulative Plastic Materials and Components

Three flat slab test samples will be molded from the vendor's first lot of certified raw materials for use in acceptance tests. Five test coupons will be cut from each test slab and tested for density, compressive strength, tensile strength, resin content, and volatile content. Individual coupons will be utilized for more than one test where possible. Test results will be tabulated and used to establish controls for subsequent lots or batches.

Three finished samples of each plastic component part, selected randomly by Thiokol, will be submitted to Thiokol for inspection and destructive testing. The following tests will be conducted: visual and dimensional inspection, X-ray for internal defects, density, tensile strength, compressive strength, resin content and volatile content. When this part successfully completes all testing, the remaining

parts in the lot will, after inspection, be incorporated into nozzles for static or environmental testing.

In addition to component part testing, the various materials bond compatibility and bond strengths will be tested. Four test samples will be made up of the materials combinations and adhesives exactly as they occur in the nozzle. Two each will be tested for bond shear, and two for tensile strength.

2.3.4.2.2 Metal Parts

Two of the structural steel components will be subjected to visual and X-ray inspection. Then each of the parts will be subjected to hydroburst testing to demonstrate that the design meets design requirements.

2.3.4.2.3 Flexible Seal Bearing

Two flexible seal bearings will be fabricated and subjected to testing. Each bearing will be installed in a test fixture and leak tested. Then each bearing will be actuated to determine actual deflection and pivot point location while pressurized. Each bearing will be tested to determine its natural frequency at various deflections. After successfully completing the above tests, each of the two bearings will be destructively tested by increasing pressure deflection angle and cycling rate until failure occurs.

2.3.4.2.4 Nozzle Assembly

One complete nozzle assembly will be subjected to temperature, humidity, and missile vibration environments. Before and at the completion of environmental testing, the nozzle will be inspected to determine its integrity. The tests will be performed in accordance with the master schedule. This nozzle then will be installed and static tested on verification motor No. 2. Nine new nozzle assemblies, fabricated using tooling, processes, and procedures intended for production, will be delivered and static tested on the development and PFRT motor static tests.

2.3.4.3 Qualification Completion

The nozzle qualification will be considered complete when the tests outlined in the preceding subsections have been conducted, and the materials and nozzle shown to meet specification requirements. Final qualification of the nozzle will be completed at the completion of PFRT Motor Testing Program.

2.3.4.4 Program Nozzles

Nozzles for the GTH, FTH, and production programs will be fabricated by the vendor qualified during the nozzle qualification effort described above.

These nozzles will be fabricated using the tooling, processes, and procedures developed and used during the fabrication of nozzles used for the motor verification and PFRT programs.

2.3.5 Ignition System Demonstration (Task 3.5)

Under this task, Thiokol will provide the personnel, service, materials, and facilities necessary to perform the design, acquisition, fabrication, assembly, and qualification testing of the ignition system. In addition, all components and materials for the motor verification, PFRT, GTH, FTH, and production programs will be received and inspected under this task. All inhouse fabrication of the ignition systems for these programs also will be conducted under this task.

2.3.5.1 System Configuration

The ignition system consists of a high mass flow rate short duration, solid propellant grain Pyrogen igniter contained in a steel case; a high mass flow rate, short duration, solid propellant grain Pyrogen initiator contained in a steel case; a pelletized pyrotechnic booster charge; and a modified KR80000 Safety and Arming Device (S&A). The igniter will utilize TP-H1016 propellant. This propellant is currently in production for use on the Minuteman Program. The ignition system will be of the configuration defined in the NASA approved Thiokol design disclosure.

2.3.5.2 Qualification Testing

Thiokol will qualify the Pyrogen igniter and Pyrogen initiator case design and fabrication by successfully hydrobursting three finished cases of each type. These cases must burst at or above design burst pressure to be considered successful.

Thiokol will conduct adhesion tests to verify the bonds between the igniter propellant, liner, and insulation. There will be 40 adhesion specimens each for the internal insulation to chamber bond, external insulation to chamber bond, propellant to liner to internal insulation bond, and nozzle insert to chamber bond.

The hydroproof and hydroburst tests will include three specimens each of pyrotechnic chamber, initiating Pyrogen chamber, and main Pyrogen chamber.

Six of the igniters will be static fired to check ignition from S & A to pyrotechnic pellets to initiating Pyrogen igniter, and ballistic performance of the initiating Pyrogen igniter. Six complete ignition systems will be static fired to check the ignition and ballistic performance of the main Pyrogen igniter and to test structural integrity and survivability of the chamber, nozzle insert and internal insulation. Two systems will be temperature conditioned to 65°F, two at 80°F and two at 95°F prior to static testing.

Qualification tests of the ignition system will consist of static firing three ignition systems after being subjected to the environmental tests of transportation vibration, handling shock, temperature, and humidity. All testing will be performed in accordance with the master schedule.

Thiokol will use a modified KR80000-09 Safety and Arming Device for Space Shuttle ignition application. This unit is the standardized S & A used on all three stages of the Minuteman Program. Modifications can be readily made to comply with manrated safety requirements. This program plan outlines the changes to be made and testing to be performed to qualify the modified S & A device for use in the Space Shuttle Program

2.3.5.2.1 Design Modifications

Modification of the KR80000-09 S & A to meet Space Shuttle requirements would consist of the following changes:

1. A new 12-pin connector will be required in place of existing 7-pin connector to provide two circuits for fire-pulse-checkout of the fire circuits in the safe position.

2. The existing 4-pin connector and wire assembly will be reworked. adding a fourth wire to provide two separate and completely redundant firing circuits.

3. A new squib source control drawing will be required to define the 1-amp. 1-watt squib, Hercules Part No. S225DO, currently manufactured by Hercules Inc. for use in the Titan S & A device. The existing squibs will be replaced with these Hercules manufactured squibs.

4. The upper switch deck and rotor and its adjacent spacer and retainer will be revised to accommodate the additional checkout circuits and redundant fire circuits. A switch similar to the one used in the KR81000 simulator will be used.

5. A new motor adapter will be used to eliminate rotor bounce.

6. A new top assembly drawing and electrical schematic drawing will be prepared to fully define the modified S & A device. A new part number will be used to identify the modified S & A device.

7. A new specification will be prepared to define the qualification and production requirements for revised S & A device.

2.3.5.2.2 Evaluation and Qualification Testing

An engineering evaluation and qualification test program consisting of the tests and quantities shown in Table 2-4 will be performed to verify the adequacies of the modifications. All testing will be performed in accordance with the master schedule.

2.3.5.3 Qualification Test Completion

The ignition system qualifications will be considered complete when 9 complete igniter assemblies have been static tested and have met the performance requirements defined in the CEI Specification. All ignition systems for the motor verification and PFRT programs will be received, inspected, and fabricated, as applicable, using the design disclosure, tooling processes, and procedures intended for use during the production program. Final qualification of the ignition system will be complete at the end of the PFRT Motor Test Program.

2.3.5.4 Program Ignition Systems

Ignition systems for the GTH, FTH, and production programs will be received and fabricated as applicable, using the tooling, processes, and procedures developed and demonstrated during the motor verification and PFRT programs.

7. A new specification will be prepared to define the qualification and production requirements for revised S & A device.

2.3.5.2.2 Evaluation and Qualification Testing

An engineering evaluation and qualification test program consisting of the tests and quantities shown in Table 2-4 will be performed to verify the adequacies of the modifications. All testing will be performed in accordance with the master schedule.

2.3.5.3 Qualification Test Completion

The ignition system qualifications will be considered complete when 9 complete igniter assemblies have been static tested and have met the performance requirements defined in the CEI Specification. All ignition systems for the motor verification and PFRT programs will be received, inspected, and fabricated, as applicable, using the design disclosure, tooling processes, and procedures intended for use during the production program. Final qualification of the ignition system will be complete at the end of the PFRT Motor Test Program.

2.3.5.4 Program Igrition Systems

Ignition systems for the GTH, FTH, and production programs will be received and fabricated as applicable, using the tooling, processes, and procedures developed and demonstrated during the motor verification and PFRT programs.

TABLE 2-4

IGNITION SYSTEM
SAFE AND ARM DEVICE QUALIFICATION TEST MATRIX

	Visual Inspection	Trans Vibration Unpackaged	Trans Vibration Packaged	Acceleration (3 axis)	Vibration (3 axis)	Life Cycles	ARM Power to Stalled Device	Temp & Humidity	Temp Altitude	Performance Testing: Both Squibs	Performance Testing: Squib No. 1	Performance Testing: Squib No. 2	Performance Testing: Squib 1 & 2 Individually	Post Test Disassemble
Engineering Evaluation (6 units)	3	6	--	6	6	6	6	--	--	--	--	--	3	--
Qualification Testing (33 units)	33 (1)	33 (1)	33 (1)	33 (2)	33 (1) (2)	1 (1)	1 (1) (2)	33	33 (1)	4	3	3	20	33 (3)

NOTES: (1) At least one electrical checkout required at this point

(2) Checkout to include fire pulse circuit check

(3) Three devices disassembled after environmental testing
Thirty devices disassembled after functional tests

2.3.6 Thrust Vector Control (Task 3.6)

Under this task, Thiokol will provide the personnel, services, materials, and facilities necessary to perform the design, acquisition, fabrication, assembly and qualification testing of the thrust vector control system. In addition, all components and materials for the motor verification PFRT, GTH, FTH, and production programs will be received and inspected under this task. All inhouse fabrication of the thrust vector control systems will be conducted under this task.

2.3.6.1 System Configuration

The thrust vector control system consists of a monofuel warm gas generator providing gas to a gas turbine which, in turn, drives a hydraulic pump. The hydraulic fluid is provided to majority voting servocontrolled tandem actuators arranged in planes 90 deg to each other in order to actuate the flexible bearing nozzle in the pitch and yaw planes. A control system to control the complete power unit in response to orbiter commands also is provided. In order to achieve high reliability two complete power systems as described above are provided to achieve system redundancy. Either system can provide 75% of the power required to actuate the nozzle through its full range at the maximum system required rate. The thrust vector control systems will be fabricated to the NASA approved Thiokol design disclosure.

2.3.6.2 Qualification Testing

Component prototype testing will be performed at the vendors. These tests are to verify the design changes to existing hardware. Development bench testing on major new components, such as the tandem actuator using majority voting servos, will require extensive vendor bench testing. Less critical actuation system components will not require breadboard demonstration at the component level. However, system verification type bench tests using prototype hardware will be performed at Thiokol preceding the final flight hardware production. Following these prototype tests, the vendors will fabricate and check out the flight hardware components. Thiokol will perform Flight System Verification tests on the entire nozzle actuation system preceding the vendor component qualification.

The qualification of the nozzle actuation system is a three-fold test. The vendors will subject four flight hardware components to full-up qualification testing including proof, temperature cycling, vibration, shock, and burst. This will be followed by complete environmental system tests at Thiokol including proof, temperature cycling, vibration, shock, hot run, and burst. Final qualification efforts will be to functionally test the full-up flight system on 10 SRM's during motor static firing. All testing will be performed in accordance with the master schedule.

2.3.6.3 Qualification Test Completion

The thrust vector control system qualification will be considered completed upon successful completion of the component and system testing described above. Final qualification will be completed upon successful completion of the motor verification and PFRT testing using the thrust vector control system on each motor static firing.

2.3.6.4 Program Thrust Vector Control Systems

Thrust vector control system for the GTH, FTH, and production programs will be received and fabricated, as applicable, using the tooling, processes and procedures developed and demonstrated during the motor verification and PFRT programs.

2.3.7 Thrust Termination (Task 3.7)

Under this task Thiokol will provide the personnel, materials, services, and facilities necessary to conduct a thrust termination system qualification program. The effort to be performed under this task consists of the design, receiving inspection, fabrication, assembly, and qualification testing of the thrust termination system. In addition, thrust termination systems for the motor verification, PFRT, GTH, FTH, and production programs will be received and inspected under this task.

2.3.7.1 System Configuration

The thrust termination system will consist of a modified Minuteman KR80000 Safe and Arm (S & A) mechanism, explosive leads and manifolds, end primers, end fitting material, two circular shaped charges, and two port stacks. The components will be fabricated to the NASA approved Thiokol design disclosure.

2.3.7.2 Qualification Testing

The qualification of the thrust termination system will include testing of the end primer, the end fitting material, and manifold. The end primer will be subjected to tests of initiation by detonator through a barrier, butt-to-butt transfer, and side initiation.

Selection of primer explosive transfer lead material will be made to meet the design requirements. The selection of internal transfer leads for the manifold and manifold material will be made to meet design requirements. The manifold will be tested for installation of looped lead, holding end tolerances, for normal propagation, and for abnormal propagation. Also, the shaped charge will be tested for ignition from various locations and angles.

Development testing for angle of penetration, standoff, charge size and penetration, and pressurized versus unpressurized vessels will be conducted using 33 complete breadboard assemblies on steel case sections with internal insulation bonded in place.

Verification testing will consist of 30 complete assemblies mounted on steel case sections with internal insulation bonded in place as shown in Figure 2-5. The entire assembly will be subjected to environmental tests of transportation vibration, flight vibration, temperature and humidity cycling, acoustic noise, and acceleration before the ignition test.

Thiokol will use a modified KR80000-09 Safety and Arming (S & A) Device for Space Shuttle thrust termination system application. This unit is the standardized S & A used on all three stages of the Minuteman missile and has demonstrated a high reliability on the Minuteman Program. Modifications can be readily made to comply with manrated safety requirements. This program plan outlines the changes to be made and testing to be performed to qualify the modified S & A device for use in the Space Shuttle program.

2.3.7.2.1 Design Modifications

Modifications of the KR80000-09 S & A to meet Space Shuttle requirements would consist of the following changes:

1. A new 12-pin connector will be required in place of the 7-pin connector to provide two circuits for fire-pulse-checkout of the fire circuits in the safe position.

2. The 4-pin connector and wire assembly will be reworked, adding a fourth wire to provide two separate and completely redundant firing circuits.

3. The existing squibs will be replaced with detonators applicable to the thrust termination requirements and the squib housing will be modified to interface with the explosive leads.

4. The upper switch deck and rotor and its adjacent spacer and retainer will be redesigned to accommodate the additional checkout circuits and redundant fire circuits. A switch similar to the one used in the KR81000 simulator will be used.

5. A new motor adapter will be used to eliminate rotor bounce.

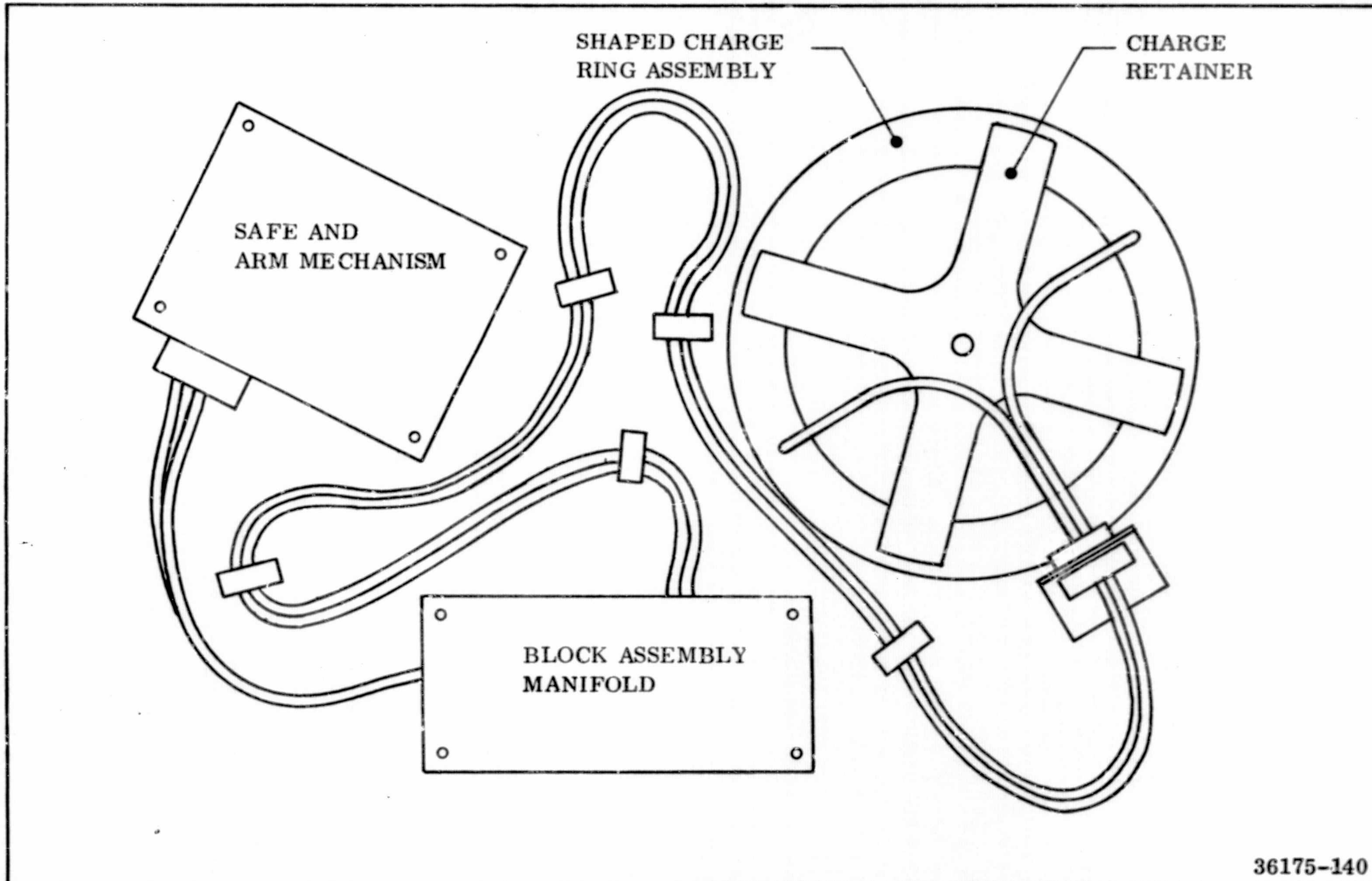


Figure 2-5. Thrust Termination System Verification Test Layout

6. A new top assembly drawing and electrical schematic drawing will have to be prepared to fully define the modified S & A device. A new number will be used to identify the modified S & A device.

7. A new specification will be prepared to define the qualification and production requirements for revised S & A device.

2.3.7.2.2 Evaluation and Qualification Testing

An engineering evaluation and qualification test program consisting of the tests and quantities shown in Table 2-5 will be performed to verify the adequacies of the modifications. All testing will be performed in accordance with the master schedule.

One complete thrust termination system will be installed on verification motor test No. 4 (DM-3). DM-3 motor will be static tested and the thrust termination system will be fired during action time. All testing will be performed in accordance with the master schedule.

2.3.7.3 Qualification Completion

To the maximum extent possible the tooling, processes, and procedures intended for production will be used during the fabrication of the thrust termination systems for component testing and the one assembly for use on the verification motor test.

The thrust termination system qualification will be considered complete when the environmentally conditioned thrust termination systems are tested successfully and meet specification performance requirements. Final qualification of the system will be complete with the thrust termination system test on DM-3.

2.3.7.4 Program Thrust Termination Systems

All thrust termination systems for the GTH, FTH, and production programs will be received, inspected, and/or fabricated under this task. All program systems will be fabricated using the tooling, processes and procedures proved out during the thrust termination system qualification effort.

TABLE 2-5

THRUST TERMINATION SYSTEM
SAFE AND ARM DEVICE QUALIFICATION TEST MATRIX

	Visual Inspection	Trans Vibration Unpackaged	Trans Vibration Packaged	Acceleration (3 axis)	Vibration (3 axis)	Life Cycles	ARM Power to Stalled Device	Temp & Humidity	Temp Altitude	Performance Testing: Both Squibs	Performance Testing: Squib No. 1	Performance Testing: Squib No. 2	Performance Testing: Squib 1 & 2 Individually	Post-Test Disassemble
Engineering Evaluation (6 units)	3	6	--	6	6	6	6	--	--	--	--	--	3	--
Qualification Testing (33 units)	33 (1)	33 (1)	33 (1)	33 (2)	33 (1) (2)	1 (1)	1 (1) (2)	33	33 (1)	4	3	3	20	33 (3)

NOTES: (1) At least one electrical checkout required at this point

(2) Checkout to include fire pulse circuit check

(3) Three devices disassembled after environmental testing
Thirty devices disassembled after functional tests

2.3.8 Power, Electrical, Avionics (Task 3.8)

Under this task Thiokol will provide the necessary personnel, materials, services, and facilities to conduct a qualification program for the power, electrical, and avionics system. The effort to be performed under this task includes the design, receiving inspection and/or fabrication, assembly and qualification of the power, electrical and avionics system. In addition, power, electrical, and avionics systems for the motor verification, PFRT, GTH, FTH, and production programs will be received and inspected and/or fabricated under this task.

2.3.8.1 System Configuration

The power, electrical, and avionics systems for the SRM Stage of the Space Shuttle consists of an instrumentation system, a malfunction detection system, and a system of electrical cables to interconnect the SRM ignition systems, the instrumentation systems, and the malfunction detection systems between the SRM's and to the Space Shuttle.

The SRM instrumentation system consists of an instrumentation enclosure containing the signal conditioners and external power switching circuits, an instrumentation battery and those end instruments required to supply subsystem events to the instrumentation enclosures.

The malfunction detection system consists of three operational pressure transducers and a solid state electronic comparator circuit to provide a chamber pressure signal to the Orbiter.

The electrical cable system consists of all the cables required to interconnect the thrust vector control, thrust termination, ignition, malfunction detection, and instrumentation system within the SRM Stage and those cables required to interconnect the SRM Stage with the Space Shuttle Orbiter.

All components and assemblies of the power, electrical, and avionics system will be fabricated to the NASA approved disclosure.

2.3.8.2 Qualification Testing

The power, electrical, and avionics system will be qualified by qualifying the individual subsystems separately and then utilizing these subsystems on the verification and PFRT motor static tests.

The instrumentation system will be qualified by subjecting the components to extreme temperature, altitude, vibration, and shock environmental testing and measuring the performance under these extreme conditions. The battery pack used for flight power in the instrumentation system will be selected from available previously flight qualified units.

Similarly, the malfunction detection system will be exposed to extreme environments and its performance measured.

The flight cable system will be qualified by fabricating representative samples and exposing these samples to thermal shock and cold bench tests and electromagnetic interference tests. Post-test inspection will verify satisfactory completion of the prescribed tests.

2.3.8.3 Qualification Completion

Qualification testing of the power, electrical, and avionics system for the SRM Stage of the Space Shuttle will be considered completed when all subsystems have passed the subsystem qualification testing and when the complete system has successfully completed the motor verification and PFRT testing programs.

2.3.8.4 Program, Power, Electrical, Avionics Systems

The power, electrical, and avionics systems for the GTH. FTH, and production programs will be received, inspected and fabricated using the tooling, processes, and procedures developed and demonstrated during the motor verification and PFRT programs.

2.3.9 Integration, Installation, Assembly and Checkout (Task 3.9)

Under this task Thiokol will provide the necessary personnel, materials, facilities, and services to perform the motor integration design, instrumentation installation design, and manufacturing finishing of the components and motors for the verification and PFRT testing programs, for the inert SRM Stages for the GTH program, the SRM Stages for the FTH program, and production programs at the launch site.

2.3.9.1 Motor Verification Program

Thiokol will furnish the necessary personnel, materials, facilities, and services to accomplish the motor integration design, static test instrumentation design and the manufacturing finishing of the components and segments for the five verification motors.

Manufacturing of the verification motors will be accomplished using production tooling, manufacturing methods, and quality control to the maximum extent possible.

Testing of the verification motors will be accomplished in Task 3.10.

2.3.9.2 Motor PFRT Program

Thiokol will provide the necessary personnel, material, facilities, and services to perform the motor integration design, the static test instrumentation design and the manufacturing finishing of the components and segments for the five PFRT motors.

The PFRT motors will be manufactured using the production tooling, manufacturing methods, and quality control techniques demonstrated in the demonstration program. All five motors will be presented for acceptance in accordance with contract requirements.

Testing of the PFRT motors will be accomplished under Task 3.10.

2.3.9.3 Solid Rocket Motor Stages for the GTH Program

Thiokol will provide the necessary personnel, material, facilities, and services to perform the GTH stage integration design and instrumentation design, and the manufacturing finishing of components and segments for the GTH stages and the delivery of the components and segments for the GTH stages.

The GTH stages will be manufactured using the production tooling, manufacturing methods and quality control techniques, as applicable, as demonstrated in the PFRT program.

The receiving, assembly, erection and checkout of the GTH stages at the launch site will be accomplished by Thiokol, using GSE provided by Thiokol (Task 7.2) and Technical data provided by Thiokol (Task 10.3).

Testing support for the GTH program will be provided by Thiokol under Task 3.10 of the Program Plan.

2.3.9.4 Solid Rocket Motor Stages for the FTH Program

Thiokol will furnish the necessary personnel, materials, facilities, and services to provide and support the Solid Rocket Motor Stage. This subtask includes the motor integration design, instrumentation design and the manufacturing final assembly operations, the delivery, assembly, erection, and checkout for the six Solid Rocket Motor Stages for the Space Shuttle Flight Test Program at Kennedy Space Center. The stages delivered under this subtask will be fabricated in accordance with the CI Specification. The motors will be fabricated immediately after the PFRT motors and the interstage structures will be fabricated immediately after completion of the component qualification program.

Completion of the PFRT Program and the Interstage Structure Qualification Program will qualify the Thiokol manufactured Solid Rocket Motor Stage for use in

the Flight Test Programs. All of the PFRT motors will have been tested and the interstage structure qualification will have been completed before flight testing at the Kennedy Space Center.

2.3.9.4.1 Flight Test Program Objectives

Primary objectives of the motor flight test program follow.

1. Provide solid rocket motor stage propulsion for the six Space Shuttle flights for the flight test evaluation program.

2. Demonstrate the flight worthiness of the Thiokol manufactured solid rocket motor stage.

3. Obtain flight data for evaluating performance of the Thiokol manufactured solid rocket motor stage.

2.3.9.4.2 Stage Configuration

The Flight Test SRM Stages, FTM-1 thru FTM-6, all will be built to the Thiokol design disclosure. In addition, the SRM Stages will be instrumented with the flight test instrumentation required to evaluate flight performance. All airborne instruments, signal conditioners and cabling will be qualified for flight use.

2.3.9.4.3 Flight Test Stage Manufacturing

The flight test motors will be manufactured immediately after the PFRT motors, and, like these motors, will utilize production tooling, processes and manufacturing, and quality control techniques which have been demonstrated and verified during the verification and PFRT Programs. Materials and components from the same vendors as those used in the verification and PFRT motors will be used in the flight test motors.

The interstage structures will be manufactured immediately after the completion of the qualification program. The structures will be manufactured using production tooling, methods and processes as demonstrated during the qualification program. Qualified vendors will be used to produce the interstage structures for the flight test program.

The flight test stages will be instrumented with flight test instrumentation. The instrumentation will be final calibrated and the calibration records retained for the motor log book.

2.3.9.4.4 Flight Test Stage Delivery

Upon completion of manufacturing site final assembly operations for the motor segments, interstage structures, and other stage components, each CI will be presented to the NASA acceptance team for interim buyoff. When interim buyoff is completed, all components of the stage will be shipped, on GBL, to the launch site. There Thiokol will receive, inspect, assemble, erect and check out the stages for the flight test program using GSE provided by Thiokol (Task 7.2) and Technical data provided by Thiokol (Task 10.3). At this point the completely assembled Solid Rocket Motor Stage will be presented to NASA for final buyoff.

Thiokol will provide the necessary personnel at the launch site to support the flight test program (Task 9.2) and will support the flight test reporting requirements of the program.

2.3.9.4.5 Flight Test Reports

The flight test reporting requirements for the Flight Test Program are, briefly:

1. TWX Report prepared by field site personnel 24 hr after each test.

2. Quick-Look Report prepared by field site personnel 10 days after each test prepared from reduced data provided by the home plant.

3. Final Report prepared by the home plant 45 days after each test.

4. Test series Summary Report prepared by the home plant.

2.3.9.4.6 Flight Test Program Completion

The SRM flight test program will be considered complete when the six flight tests have been completed. Individual motors will be considered successful if they meet the requirements of the Flight Test Appendix to the CI Specification, Part I, Technical Requirements, as further defined by the Thiokol provided design disclosure.

2.3.10 Ground Test (Task 3.10)

Under this task, Thiokol will provide the necessary personnel, material, facilities, and services for assembly, static test, and post-test reporting for the verification motor static tests, the PFRT static tests, and the personnel to support the two solid rocket motor stages during the GTH program at the operational site. Thiokol also will conduct all process control testing during the production program under this task.

2.3.10.1 Motor Verification Program

Thiokol will furnish the necessary personnel, materials, facilities, and services to conduct the verification motor testing program. This subtask covers the test assembly, testing, and reporting efforts necessary to successfully verify that the Solid Rocket Motor meets the requirements of the Configuration Item (CI) Specification. A minimum of five motors will be tested to accomplish this verification. The motor matrix (Table 2-1) provides a description of the configuration requirements, test requirements, and test conditions for each of the planned five motors to be tested.

2.3.10.1.1 Motor Verification Program Objectives

The primary objectives of the Motor Verification Program are as follows.

1. Verify the ability to process and manufacture motors to the Thiokol designs and specifications.

2. Verify the ability to produce motors to the NASA approved design disclosure, with reproducible configuration and performance parameters.

   a. Verify handling and processing techniques.

   b. Verify quality control and inspection techniques.

   c. Verify fabrication and assembly flow and facility usage.

   d. Verify production tooling designs.

3. Demonstrate three successive successful static tests of the motor.

4. Obtain component and motor performance data before initiating the PFRT Program.

5. Obtain data on performance of the thrust termination system.

2.3.10.1.2 Verification Motor Configuration

Verification Motors 1 and 2 (DM-1, DM-2) will be of the configuration defined in the Thiokol design disclosure with static test instrumentation added. One forward, one center, and one aft segment from DM-2 will be subjected to temperature cycling prior to assembly into DM-2 motor for static test.

DM-3 will be of the configuration defined in the Thiokol design disclosure with a thrust termination system and static test instrumentation added.

DM-4 and DM-5 will be of the configuration identified in the Thiokol design disclosure with static test instrumentation added.

DM-1 and DM-2 will be manufactured as early in the program as possible. These two motors will be used primarily to verify component sources and processing techniques. They will be built to the Thiokol design disclosures. Production tooling and manufacturing methods that are defined adequate and available will be used. Nonproduction tooling is anticipated for insulation manufacturing, propellant transfer operations, and for motor weighing and center of gravity determination. All other tooling and manufacturing methods used will be those intended for production.

DM-3, DM-4 and DM-5 will be manufactured using final production tooling and manufacturing methods. These motors will provide manufacturing methods and tooling checkout prior to beginning the PFRT Program. DM-5 will be presented for acceptance in accordance with contract requirements.

2.3.10.1.3 Verification Motor Testing

Before testing each of the demonstration motors, a test request will be prepared and submitted 20 calendar days before the test. The test request will be prepared in accordance with contract requirements. The test request will define the test configuration, test conditions, test instrumentation, data acquisition system requirements, data reduction requirements, and photographic coverage requirements.

DM-1 will be conditioned to 70°F and fired horizontally. Approximately 212 channels of instrumentation will be used to measure and record axial thrust, side thrust, igniter pressure, chamber pressure, nozzle position, HPU events, case and nozzle strain, and accelerations. Six cameras will be used for photographic coverage of the test. Cameras will be focused on the individual parts to determine the firing action and exhaust plume pattern.

DM-2 using forward, one center and aft segments which have been subjected to temperature cycling testing will be temperature conditioned and static tested essentially the same as DM-1. Approximately the same instrumentation and photographic coverage will be used.

DM-3 will be static tested as a thrust termination verification. Approximately 165 channels of instrumentation will be used to measure and record axial thrust, igniter pressure, chamber pressure, thrust termination events, and accelerations. Photographic coverage of the static test will be provided. Thrust termination will be initiated at approximately 50 percent of action time.

DM-4 will be static tested essentially the same as DM-1. The test setup and instrumentation will be essentially the same as for DM-1.

DM-5 will be static tested after it has been accepted by NASA. DM-5 will use forward, one center and aft segments which have been subjected to transportation and handling acceleration simulation testing. The motor configuration will be in accordance with the Thiokol design disclosure, as will be demonstrated in the acceptance meeting. DM-5 will be temperature conditioned to approximately 80°F prior to firing.

2.3.10.1.4 Static Test Reports

The static test reporting for the Motor Verification Program will briefly be as follows.

1. TWX Report 24 hours after each test,

2. Quick-Look Report 10 days after each test,

3. Final Report 30 days after each test, and

4. Test Series Summary Report 45 days after the last test.

2.3.10.1.5 Motor Verification Program Completion

The Motor Verification Program will be considered complete and successful after three successive successful firings have been conducted. Individual motor success will be based on meeting criteria defined in the CI Specification, Part I, Technical Requirements, and the Thiokol provided design disclosure.

2.3.10.2 Motor PFRT Program

Thiokol will furnish the necessary personnel, materials, facilities, and services to conduct the PFRT Program. This subtask includes the test assembly,

testing, and reporting effort required to successfully qualify the Thiokol motor for use in the Space Shuttle Flight Test Program at Kennedy Space Center and demonstrate that the motor meets the requirements of the CI Specification. Five motors will be manufactured and tested to accomplish this verification. The motor matrix (Table 2-1) provides a description of the configuration requirements, test requirements, and test conditions for the five motors in the PFRT Program.

2.3.10.2.1 PFRT Program Objectives

The primary objectives of the Motor PFRT Program follow.

1. Qualify the Thiokol manufactured motor for use in the Space Shuttle Flight Test Program at Kennedy Space Center.

2. Successfully accomplish the environmental and static testing described for motors in the test plan.

2.3.10.2.2 Motor Configuration

The PFRT motors, PFRT-1 thru PFRT-5, will be built to the Thiokol design disclosure with one exception: static test instrumentation will be added.

2.3.10.2.3 PFRT Motor Testing

Before the start of testing, a PFRT Test Plan will be prepared. The test plan will define the overall program objectives, the types and sequences of tests to be conducted to satisfy these objectives, motor acceptance procedures, test apparatus and procedures, test conditions, and motor test and inspection requirements. This test plan will be submitted for approval, and upon approval, will be used to conduct the test program. Detailed test requests will be submitted for each of the five motor tests in accordance with the approved program test plan. The test request will define the test configuration, test conditions, test instrumentation, data acquisition requirements, data reduction requirements, and photographic coverage requirements for each specific motor test.

All PFRT motor subsystems will be operable and will be used during the static tests. The motors will be conditioned to 70°F for the static firing. Approximately 212 channels of instrumentation will be used to measure axial and side thrust, accelerations, case and nozzle strains, pressure events, HPU performance and nozzle position. In addition, six cameras will be used for photographic coverage of the test.

2.3.10.2.4 Static Test Reports

The static test reporting requirements for the PFRT Program are:

1. TWX Report 24 hours after each test,
2. Quick-Look Report 10 days after each test,
3. Final Report 30 days after each test, and
4. Test Series Summary Report 45 days after the last test.

2.3.10.2.5 PFRT Program Completion

The PFRT Program will be considered complete when the five motor static tests have been completed successfully, and approval of the final PFRT Summary Report has been received from NASA. Individual motor success will be based on meeting the criteria defined in CI Specification, Part I, Technical Requirements, as further defined by the Thiokol design disclosure.

2.3.10.2.6 PFRT Schedule Options

If Verification Motors 1, 3, 4 and 5 are successful, Thiokol recommends the use of Verification Motor 5 as the first PFRT motor, advancing the schedule. The configuration and manufacturing techniques for the motors have been established to permit this action.

2.3.10.3 Motor Post-Test Analysis and Storage

Under this subtask, Thiokol will provide personnel, material, services, and facilities necessary to perform a thorough post-test analysis of fired verification and PFRT motors, evaluate motor and component performance, and evaluate manufacturing techniques. All verification and PFRT motors will be disassembled and/or dissected after static firing to allow complete inspection and analysis of components and processing techniques.

2.3.10.3.1 Motor Disassembly

Before removal of each motor from the test stand, complete visual and still photo documentation will be accomplished. The motor then will be disassembled in the test stand whereby major components, i.e., nozzle, case (segments), and ignition, will be removed.

2.3.10.3.2 Case Inspection

The verification motor cases and the PFRT motor cases will be visually inspected for hot spots, distortion, etc. The remaining virgin internal case insulation material will be measured along the length of the case segments. The insulation around thrust termination ports will be measured on the motor which had a hot thrust termination test. Thrust termination port throats will be measured and thrust termination ports, bellows, and stacks will be examined for clean lines of cut and remaining structural integrity.

2.3.10.3.3 Ignition System Inspection

The ignition systems from all motors will be visually examined before removal. The verification and PFRT motor ignition systems will be disassembled and examined, and remaining insulation thicknesses measured.

2.3.10.3.4 Nozzle Inspection

The nozzle plastic, rubber, and metal components will be separated by heat soaking in an oven to break down adhesive bonds. The parts will be longitudinally sectioned to permit measurement of the throat, exit cone, and entrance section to determine erosion rates. Differential erosion patterns will be determined and measured. Bonded interfaces, seals, external surfaces, and structural parts will be examined for detrimental condition. The throat will be examined for cracking, washing, pitting, and erosion patterns.

2.3.10.3.5 Thrust Vector Control System Inspection

The thrust vector control system will be inspected for hydraulic leaks, hot spots on the gas generator, and general condition prior to disassembly. Upon disassembly, the gas generator will be dissected and examined for erosion patterns and internal insulation condition. The gas turbine, hydraulic pump, and tandem actuators will be disassembled and examined for erosion and wear. The condition of all components will be thoroughly documented with photographs.

2.3.10.3.6 Power, Electrical, Avionics System Inspection

The power, electrical, avionics systems, and the thrust vector control system control unit will be subjected to complete post-test electrical and electronic calibrations and then will be disassembled and checked for any internal damage. Again, the condition of all systems and components will be documented with photographs.

2.3.10.3.7 Inspection Documentation

Post-test documentation will include complete still photographic coverage of systems, components, and parts before and after disassembly and/or dissection, dimensional data, identification of parts and pieces as related to fired configuration, erosion data, a description of the observed condition of all elements, and results of any prior test calibration or testing.

Post-test analysis of static fired hardware will provide a thorough examination of the condition of all elements of the motor and analysis of all post-test calibration and testing. Performance then can be evaluated and compared to the specification requirements.

2.3.10.3.8 Storage

All remaining motor components, including disassembled and/or dissected hardware, will be stored pending NASA direction for disposal.

2.3.10.4 Solid Rocket Motor Stage Ground Test Program

Thiokol will provide the necessary personnel, materials, and services to provide support for the Solid Rocket Motor Stage during the GTH Test Program at the test site. The two stages to be tested under this program will be configured to meet the Ground Test Program requirements.

2.3.10.4.1 Ground Test Program Objectives

Primary objectives of the Ground Test Program are as follows.

1. Demonstrate the capability of the SRM Stage to withstand all static and dynamic loads associated with Space Shuttle transportation from the VAB to the launch pad.

2. Demonstrate the capability of the SRM Stage to withstand all static and dynamic loads associated with countdown, ignition and liftoff.

3. Demonstrate the capability of the SRM Stage to withstand all static and dynamic loads associated with staging of the SRM Stage.

2.3.10.4.2 Motor Configuration

GTM-1 and GTM-2 will be fabricated using refurbished hardware from the Verification Motor Program and the Component Qualification Program. GTM-1 will

be empty to simulate a burned out SRM Stage and GTM-2 will be loaded with inert propellant to simulate a fully loaded SRM Stage immediately prior to ignition. All components of both GTM's will be inert but will be configured to allow complete ground check simulation and flight simulation. S & A simulators will be provided for each S & A on the SRM Stage.

2.3.10.5 Production Process Control Testing

All production process control testing will be developed and documented during the component qualification testing and the verification and PFRT motor testing programs. The documentation will consist of complete disclosure of production process control requirements in the Part II Configuration Item Specifications, and raw materials and component specifications.

Raw material process control will consist of vendor control through the application of specifications and standards controlling the processing of raw materials. In addition, receiving sampling and inspection of all raw material lots will be accomplished.

Component process control will be achieved through the proper application of tooling control and inspection and component inspection, either at vendor plants or inhouse. All components will be inspected to the degree warranted by their complexity and effect upon Space Shuttle system performance.

A method of propellant production process control will be used to assure consistent reproducible performance of SRM's provided for the Space Shuttle Program. This method consists of making liquid strand burning rate tests, infrared spectrographic analysis, and total solids analyses of each batch of propellant for acceptance prior to being cast into a segment. All parameters must be within specification limits or the batch of propellant is immediately scrapped by the engineering representative on the Material Review Board. From the first, middle, and last batch of propellant in each segment, three 5-in. diameter, center perforate ballistic evaluation motors will be cast and three 1-gal loaf samples will be cast. The ballistic test motors will be fired to allow prediction of the ballistic performance of the segment and the loaf samples will be tested to verify the physical properties of the propellant in each segment.

2.4 INTERSTAGE STRUCTURES (PROJECT 4)

Under this project Thiokol will provide the necessary personnel, materials, services, equipment, and facilities to perform the design, receiving inspection, and component qualification for the interstage structures for the SRM Stage of the Space Shuttle. In addition, Thiokol will receiving inspect the interstage structures for the GTH, FTH, and production programs under this task. Component design, receiving inspection, and qualification are discussed in detail in the following paragraphs.

2.4.1 Struts, Thrust and Sway (Task 4.1)

Under this task, Thiokol will provide the necessary personnel, facilities, materials, and services to perform the design, receiving inspection and qualification testing for the struts, thrust and sway. These components are required to attach the SRM to the orbiter tank, to transmit thrust from the SRM to the orbiter tank, and to stabilize the SRM with respect to the orbiter tank.

2.4.1.1 Component Configuration

The struts, thrust and sway consist of two main thrust transmission struts between the nose fairing on each SRM and the orbiter tank, two braces between the aft fairing on each SRM and the orbiter tank to transmit side loads, and several sway braces to stabilize the SRM to the orbiter tank.

Each of these components is a steel tubular structure with forged steel end fittings with the size and wall thickness of each component designed for its application. The struts will be fabricated to the NASA approved Thiokol design disclosure.

2.4.1.2 Component Qualification

Component qualification will be accomplished in two phases. The first phase consists of static load and stiffness testing ten units of each component to failure. The second phase consists of utilizing two complete sets of struts, thrust and sway in the complete assembly static structural tests described in tasks 4.2 and 4.3 above.

2.4.1.3 Qualification Completion

The qualification of the struts, thrust and sway will be completed upon completion of the static testing described above and in tasks 4.2 and 4.3. Final qualification will be completed after successful completion of the GTH and FTH programs at the launch site.

2.4.1.4 Program Components

All struts, thrust and sway for the GTH, FTH, and production programs will be fabricated using the tooling, processes and procedures developed during the qualification program. In addition, all struts, thrust and sway for the GTH, FTH, and production programs will be receiving inspected under this task.

2.4.2 Nose Fairing (Task 4.2)

Under this task Thiokol will provide the necessary personnel, facilities, materials, and services to design, receiving inspect, and qualify the nose fairing for the SRM Stage of the Space Shuttle. The nose fairing is required to provide aerodynamic fairing of the forward end of the SRM and to provide for SRM thrust transmission from the forward skirt of the SRM to the main thrust struts.

2.4.2.1 Component Configuration

The nose fairing is a conical aluminum monocoque structure with a hemispherical nose cap. The nose fairing interfaces with the SRM forward skirt and provides attachment for the main thrust struts between the SRM and orbiter tank. The full thrust load of the SRM is transmitted from the SRM forward skirt through the nose fairing to the thrust struts. The nose fairing will be fabricated to the NASA approved Thiokol design disclosure.

2.4.2.2 Component Qualification

The nose fairing qualification will be accomplished by subjecting four nose fairings to the following tests. Two nose fairings will be pressure loaded to simulate flight dynamic pressure loading. Each of these two nose fairings will be pressure loaded to predicted flight dynamic pressure loading and strain and displacements will be recorded. Each then will be pressurized to destruction. Two nose fairings will be used for structural load tests. Each will be built up into an assembly with a forward motor closure, main thrust struts, and sway braces. These assemblies will be structurally loaded to destruction simulating as closely as possible the flight load conditions.

2.4.2.3 Qualification Completion

The qualification of the nose fairings will be completed upon successful completion of all structural and pressure testing. Final qualification of the nose fairing will be completed upon successful completion of the GTH and FTH programs at the operational site.

2.4.2.4 Program Components

All nose fairings for the GTH, FTH, and production programs will be fabricated using the tooling, processes, and procedures developed and verified during the qualification program. All nose fairings for the GTH, FTH and production programs will be receiving inspected under this task.

2.4.3 Aft Fairing (Task 4.3)

Under this task, Thiokol will provide the necessary personnel, facilities, materials, and services to design, receiving inspect, and qualify the aft fairing for the SRM Stage of the Space Shuttle. The aft fairing is required to provide aerodynamic fairing at the aft end of the SRM, provide protection during flight to the nozzle and thrust vector control components, provide for SRM side thrust transmission from the aft end of the SRM to the side thrust struts, and provide Space Shuttle holddown capability.

2.4.3.1 Component Configuration

The aft fairing is a conical composite steel and aluminum structure. The aft fairing interfaces with the SRM aft skirt and provides attachment for the side thrust struts between the SRM and Orbitor tank. The aft fairing provides an attachment structure capable of holding the Space Shuttle vehicle on the pad during SRM burning throughout action time. The side thrust load of the SRM is transmitted from the SRM aft skirt through the aft fairing to the side thrust struts. The aft fairings will be fabricated to the NASA approved Thiokol design disclosure.

2.4.3.2 Component Qualification

The aft fairing qualification will be accomplished by subjecting two aft fairings to the following structural load tests. Each will be built up into an assembly with an aft motor closure, side thrust struts, and sway braces. These assemblies will be structurally loaded to destruction simulating closely as possible the flight load conditions and the load condition experienced while holding the Space Shuttle vehicle on the pad while the SRM's burn out.

2.4.3.3 Qualification Completion

The qualification of the aft fairings will be completed upon successful completion of all structural testing. Final qualification of the aft fairing will be completed upon successful completion of the GTH and FTH programs at the operational site.

2.4.3.4 Program Components

All aft fairings for the GTH, FTH, and production programs will be fabricated using the tooling, processes and procedures developed and verified during the qualification program. All aft fairings for the GTH, FTH, and production programs will be receiving inspected under this task.

2.5 FACILITIES (PROJECT 5)

Under this project, Thiokol will provide the personnel, materials, services and facilities necessary to define, design, develop, acquire or build the new or modified facilities required to support the fabrication of the SRM Stage for the Space Shuttle program. The new or modified facilities will be maintained and repaired throughout the life of the program.

2.5.1 In-Plant Facilities

Thiokol plans to conduct the DDT & E and production programs at the Wasatch Division which is located 27 miles west of Brigham City, Utah. This facility consists of the corporate-owned Research and Development Plant (R&D Plant) and the Government owned, Thiokol operated plant designated as Air Force Plant 78. Actually since 1963 these two plants have been operated on a "single plant" concept, wherein the R&D Plant and AF Plant 78 are considered as a single manufacturing facility.

The requirements of the DDT & E and production programs are such that all of the Space Shuttle work can be integrated with programs presently on board without impact or conflict. This is true even though it was assumed that the present business level (thus, facility utilization) would continue for the duration of the Space Shuttle DDT & E and production programs. The programs presently on board, considered for possible interference at maximum projected production rates are as follows.

Stage I Minuteman Production

Stage III Minuteman Production

Poseidon Production

Genie Production

SRAM Development followed by Production

LUU-2/B Flare Production

New facilities and modifications to existing facilities will be required to support certain operations which are unique for the 156-in. SRM segments. A relatively small amount of these facility costs are appropriately considered a direct program charge whereas the balance represents a capital investment for Thiokol. The total facilities required to support the DDT & E and production programs are shown in Tables 2-6 and 2-7.

TABLE 2-6

SPACE SHUTTLE
VERIFICATION PROGRAM FACILITIES (DDT & E)

Area	Bldg	Requirement	Quantity (ea)	Design (hr)	Install (hr)	Purchase ($)	Corporate Funded ($)
Case Prep	M-111	Remove section of partition	--	20	50	100	--
		Relocate existing bench work	--	100	800	500	--
		Provide benches and stools	10	--	--	--	2,000
		Run utilities to work stations	--	100	350	1,000	--
		Replace hoist and trolley	1	--	--	--	10,000
	M-67	Mixer adhesive	--	--	--	--	1,500
Lining	M-111	Exhaust system (mek)	--	--	--	--	10,000
		Liner, Mixer (75 gal.)	--	--	--	--	25,000
Propellant	Pits	Gantry crane modification	--	--	--	--	30,000
		Casting house modification	--	--	--	--	5,000
		Vacuum pump (500 cfm)	--	--	--	--	8,000
		Polywax building	--	--	--	--	75,000
		Pit covers	2	--	--	--	16,000
		Pads for segment at pit	2	--	--	--	3,000
	M-120	Premix building addition	--	--	--	--	120,000
		Feed, weigh, premix system	--	--	--	--	223,000
		Bins (95 cu ft)	10	--	--	--	10,000
	M-39	Apportioning system	--	--	--	--	100,000
	M-20	Conveyor, mixer feed pilot	--	--	--	--	145,000
X-ray	New	X-ray building	--	--	--	--	437,000
	New	Boiler house	--	--	--	--	70,000
		Relocate 13 mev LINAC	--	680	1,200	2,000	--
		Foundation for jack station	--	20	400	4,000	--
Assembly	M-67	Enlarge doors	2	160	0	15,000	--
		Exhaust	--	--	--	--	5,000
		Run utilities to work stations	--	60	100	200	--
		Foundation jack station	--	20	400	4,000	--
		Painting station	--	--	--	--	45,000
Handling		Tractor/Trailer (200 ton)	--	--	--	--	270,000
		Pads, case, & nozzle storage	--	--	--	--	4,500
Flexible bearing	M-508	Oven heat treat	--	--	--	--	500,000
		Ultrasonic tank	--	--	--	--	1,500
		Rotator	--	--	--	--	1,500
		Scale (100 lb.)	--	--	--	--	1,800
		Conveyor (190 ft)	--	--	--	--	30,000
		Press, compression molding 8 x 8 ft	--	--	--	--	145,000
		Cold box 8 x 8 x 8 ft	--	--	--	--	6,000
		Exhaust hood	--	--	--	--	6,000
		Spray booth	--	--	--	--	10,000
Quality	M-8	Rotary table (180 in.)	--	--	--	--	200,000
		Surface plate	--	--	--	--	10,000
		Process control lab equipment	--	--	--	--	95,000
Test	T-24	Modify bay	--	--	--	--	400,000
		Temporary pump installation	--	350	800	4,000	--
		Thrust termination pad	--	3,500	0	457,600	--
		Conditioning chamber	--	--	--	--	140,000
		Data system mobile	--	--	--	--	200,000
		Board course rehabilitation	--	120	1,000	10,000	--
		Hydroburst pad	--	200	1,000	2,000	--
	T-53	Add instrumentation	--	--	--	--	50,000
		cameras	5	--	--	--	20,000
				5,330	6,100	$500,400	$3,431,800

TABLE 2-7

SPACE SHUTTLE
PRODUCTION PROGRAM FACILITIES
60 FLIGHTS A YEAR

Area	Bldg	Requirements	Quantity (ea)	Design (hr)	Install (hr)	Purchase ($)	Corporate Funded
Casting	Pits	Pit covers	10	--	--	--	120,000
		Pads at pits	14	--	--	--	21,000
		Mod casting house	--	--	--	--	70,000
		Motorize casting house	--	--	--	--	20,000
		New casting house	--	--	--	--	195,000
		Mod gantry (50 tons)	--	--	--	--	30,000
		Gantry crane (200 tons)	2	--	--	--	600,000
		Mod gantry (200 tons)	--	--	--	--	20,000
		Rehabilatation pits	2	1,960	9,000	68,300	--
		New pits west of existing	2	--	--	--	268,500
		New pit in new complex	--	--	--	--	172,200
		Utilities, road	--	--	--	--	48,500
		Cooling system, mobile	3	--	--	--	60,000
		Vacuum pump	2	--	--	--	16,000
Mixing		Mix bowls	4	--	--	--	60,000
		Trailers, mix bowl	6	--	--	--	21,000
		Conveyorize mixer feeding	3	--	--	--	450,000
	M23	Mixer (600 gal)	--	--	--	--	330,000
		Mixer buildings & mixer (600 gal)	2	--	--	--	1,000,000
		Dump station (replace M23)	--	--	--	--	70,000
		Addition to mixer control	--	--	--	--	40,000
Oxidizer	M39	Mod for grinding	--	--	--	--	480,000
		Bins (35 cu. ft.)	2	--	--	--	2,000
Painting		Painting building w/equip	--	--	--	--	140,000
		Compressor	--	--	--	--	5,000
		Foundations jackstand	2	40	400	4,000	--
Quality		Additional QC lab equipment	--	--	--	--	50,000
Storage		Pad, cases	--	--	--	--	70,000
		Pad, nozzles	--	--	--	--	45,000
		Crane mobile	--	--	--	--	100,000
		Cold box 40 x 40 x 14 ft	--	--	--	--	100,000
		Motor surge area	--	--	--	--	250,000
		Foundations, motor surge	10	200	2,000	20,000	
Transport		Tractor/Trailer (200 tons)	--	--	--	--	540,000
X-ray		Linear accelerators (15 mev)	3	--	--	--	1,025,000
		Film processors	3	--	--	--	51,000
		X-ray building	--	--	--	--	430,000
		Foundations jackstand	3	60	600	6,000	--
		Roadway	--	--	--	--	50,000
		Fencing	--	--	--	--	10,000
		Warning system	--	--	--	--	8,500
Assembly		Foundation jackstand	--	20	200	2,000	--
		Compressor, central	--	--	--	--	75,000
Utilities/ Services		Addition to boiler house	--	--	--	--	70,000
		Addition to maintenance shop	--	--	--	--	110,000
		Office furniture and equipment	--	--	--	--	300,000
		Addition to change house	--	--	--	--	75,000
Flexible Bearing		Lathe VTL	3	--	--	--	600,000
				2,280	12,200	100,300	$8,198,200

2.5.2 Operational Site Facilities

During the GTH, FTH, and production programs, there will be a need for facilities at the launch site. These facilities will be provided by NASA for use by the contractor during the programs cited above.

A receiving inspection, storage and subassembly (RISS) building will be required at the launch site. This building will be approximately 30,000 square feet in floor area. A 200-ton capacity gantry crane covering the complete floor area will be required. The necessary offices, change rooms, restrooms, water, power, and air conditioning must be provided. It will be necessary to control the temperature in this building to approximately 70 - 80°F in order to be able to accurately predict SRM performance after storage in the RISS building.

A railroad spur track from existing tracks at the launch site to the RISS building will be required to facilitate transportation of the SRM components directly to the RISS building.

A road capable of withstanding continued usage by rubber-tired low-bed truck-trailer combinations with a gross combination weight of approximately 200 tons will be required from the RISS building to the vehicle assembly building (VAB).

One other significant facility required is a segment transfer building and 200 ton capacity gantry crane at the railhead near the Thiokol plant in Utah. This facility is required to transfer the SRM segments from the inplant transporter to the rail car for shipment. The building required is only a weather shelter with no heat or air conditioning required.

2.5.3 Vendor Facilities

Vendor facilities requirements have been identified for both the DDT & E program and the production program.

During DDT & E, facilities will be required by the vendors for case forging and case machining and the vendor for nozzle fabrication. The estimated facilities costs are $2,994,200.

During production, additional facilities will be required by the above vendors and in addition a major facility expansion will be required by the ammonium perchlorate vendor. The total estimated cost for these facilities is $101,603,000.

2.6 TOOLING (PROJECT 6)

Under this project, Thiokol will provide the personnel, materials, and services to design and fabricate or acquire the special tooling, inplant handling equipment, support equipment, and special test equipment required to fabricate, deliver and test the Solid Rocket Motor Stage for the Space Shuttle.

The Thiokol tooling concept for the program will be based on the following guidelines.

1. Hard tooling used from the outset with complete hard tooling available for production of all PFRT motors and flight test stages. Application of this policy provides a greater measure of reliability, reduces part-to-part variation, produces cost savings, and provides a more realistic evaluation of component designs, manufacturing processes, and tool design before commencement of delivery units.

2. Employment of tool proofing before motor use. Tool proofing is verification that special tooling will produce component parts that consistently meet all design requirements.

3. Use of specific periodic recycle inspection of all configuration controlling tools and other tools critical to the manrating requirement.

Thiokol will provide tooling and special test equipment inplant and at subcontractors in quantities sufficient to meet the master schedule shown in Figure 2-1.

Vendor tooling will be controlled in a manner which assures compliance with the basic requirements of applicable Government regulations and the general company policies. This control is imposed by the procurement documents, and includes provision for review of the tooling designs to (1) assure that basic quality and safety aspects have been satisfied, and (2) provide for approval of the tool control systems to be utilized by the vendors.

A review and approval of all special tooling design drawings by a representative of the Safety Office is required prior to release of the design. This review assures an objective, detailed analysis of the design concept and details of the special tool by a trained Safety Engineer. In addition, an established Safety Committee, comprised of representatives, from the operating organizational elements meets regularly to review and assess safety requirements for all aspects of all programs. General concepts involving special tooling, or details of special tools, can be brought to this

Committee for review by any member, thus assuring an even broader assurance of the consideration of safety as regards special tooling.

A review and approval of all special tooling design drawings by a representative of Quality Assurance Engineering is required prior to release of the drawing. This review, like that of the Safety Engineer, assures an objective, detailed analysis of the design concept and details by a trained Quality Engineer. This analysis assures that the tool can be adequately inspected, its quality determined, and assures that the tool, when used, will perform its function adequately with no quality deterioration of the components.

Allowances have been made, based on over 10 years of plant experience, for maintenance and repair of the tooling and special test equipment as needed during the life of the DDT & E and production programs.

The special tooling and test equipment requirements are shown in Tables 2-8 thru 2-16.

TABLE 2-8

CASE PREPARATION SPECIAL TOOLING

Tool Name	DDT & E Quantity	Total Production Quantity
Vertical Stand	1	0
Headend Plug	1	0
Aft End Plug	1	0
Handling Arrangement	1	0
Grit Blast Dolly	1	1
Work Platform	1	1
Degreasing Seal and Wand	1	1
Roller Assembly	1	4
Work Stand - Vertical	1	1
Pneuma-Grip Harness	2	3
Handling Fixture, Skirt Extension	1	1
Insulation Mold Ring (Shims included)	6	12
Handling Sling	1	1
Chocks	2	10

TABLE 2-9

INSULATION SPECIAL TOOLING

Tool Name	DDT & E Quantity	Total Production Quantity
Cutting Table	1	1
Cutting Dies	1	1
Patterns	1	1
Work Platform - Forward	1	1
Work Platform - Center	1	3
Work Platform - Aft	1	1
Roll Feeding Assembly - Forward	1	1
Roll Feeding Assembly - Center	1	3
Roll Feeding Assembly - Aft	1	1
Skiving Machine	1	4
Rollers	2	8
MEK Applicator	2	8
Insulation Contour Template - Forward	1	1
Insulation Contour Template - Center	1	2
Insulation Contour Template - Aft	1	1
Vacuum Bag - Forward	1	2
Installation Tool, Vacuum Bag - Forward	1	2
Vacuum Bag - Aft	1	2
Installation Tool, Vacuum Bag - Aft	1	2
Vacuum Bag - Center	1	3
Holding Fixture - Magnetic - Center	3	5
Autoclave Dolly	2	3
Handling Fixture Insulation Mold Ring	1	1
Machining Fixture - Joint	1	1

TABLE 2-10

PROPELLANT AND LINING SPECIAL TOOLING

Tool Name	DDT & E Quantity	Total Production Quantity
Handling Harness	1	2
Lifting Beam - Vertical	2	4
Work Stand	1	2
Breakover Trailer	1	1
Rotating Dolly	2	3
Handling Dolly - Harness	1	2
Insulated Conical Container	1	1
Casting Arrangement - Forward	1	1
Casting Arrangement - Center	1	1
Casting Arrangement - Aft	1	1
Casting Base - Center - Aft	1	9
Core - Center	1	9
Core - Dolly - Center	1	9
Mold - Aft End	2	12
Centering Ring - Core	2	12
Casting Funnel	1	3
Air Deflector	2	15
Vacuum Bell	1	3
Deaeration Assembly	1	3
Transfer Hopper Assembly	1	3
Core - Aft	1	3
Casting Sleeve	2	12
Casting Dam	1	3
Skirt Protector	1	3
Headend Alignment Sleeve	1	3
Casting Stand	2	15

TABLE 2-10 (Cont)

PROPELLANT AND LINING SPECIAL TOOLING

Tool Name	DDT & E Quantity	Total Production Quantity
Core - Forward	1	3
Casting Stand Adapter - Forward	1	3
Casting Stand Adapter - Aft	1	3
Core Dolly - Forward	1	3
Core Dolly - Aft	1	3
Exhaust Hood	1	1
Lining Pit Stand	3	3
Liner Masking Sleeve	3	3
Liner Cure Seals	3	3
Weighing Tools	1	2
Deaerator	1	2
Sling Assembly	1	1
Core Popping Arrangement	1	1
Work Grating	1	3
Pit Grating	2	15
Overcast Propellant Press	1	1

TABLE 2-11

IGNITER SPECIAL TOOLING

Tool Name	DDT & E Quantity	Total Production Quantity
Vibration Arrangement	1	0
Vibration Fixture	1	0
Firing Arrangement	1	1
Test Stand (O) Component	1	1
Lifting Beam	1	1
Layup Dolly - Horizontal	1	2
Insulation on Mold Ring	2	4
Vacuum Bag	1	2
Handling Dolly - Case	5	5
Handling Sling	1	1
Aft Grain Mold	12	12
Casting Sleeve	12	12
Core Guide	12	12
Core	12	12
Core Retainer	12	12
Casting Adapter	3	3
Casting Piping	1	1
Core Popper	1	1
Handling Container	20	30
Casting Arrangement	1	1

TABLE 2-12

NOZZLE SPECIAL TOOLING

Tool Name	DDT & E Quantity	Total Production Quantity
Handling Fixture Actuator	1	1
Holding Fixture	1	1
Holding Fixture	1	1
Mounting Tool - Magnetic Particle Inspection	1	1
Drill Fixture	1	1
Tank and Rotab Ultrasonic Inspection	1	1
Handling Sling	1	1
Handling Sling Assembly	1	1
Hold-down Clamp and Riser Shim	1	1
Holding Fixture	2	2
Drill Fixture	1	1
Work Stand - Mold	1	1
Mold	1	1
Lifting Sling	1	1
Holding Fixture - VTL	1	2
Special Dial Bar Gage	2	2
Vacuum Holding Fixture No. 1	1	1
Vacuum Holding Fixture No. 2	1	1
Vacuum Holding Fixture No. 3	1	1
Vacuum Holding Fixture No. 4	1	1
Vacuum Holding Fixture No. 5	1	1
Vacuum Holding Fixture No. 6	1	1
Vacuum Holding Fixture No. 7	1	1
Vacuum Holding Fixture No. 8	1	1
Vacuum Holding Fixture No. 9	1	1
Rotating Table	1	1

TABLE 2-12 (Cont)

NOZZLE SPECIAL TOOLING

Tool Name	DDT & E Quantity	Total Production Quantity
Work Stand - MEK	1	1
Work Stand - Drying	1	1
Spray Booth Tools	1	1
Work Stand - Layup	1	1
Work Stand - Cutting	1	1
Work Stand - Assembly	1	1
Work Stand - Assembly	1	1
Work Stand - Hand Trim	1	1
Work Stand - Layup	1	1
Work Stand - Bonding	1	1
Flexible Joint Mold	1	1
Insulation Blanket	1	1
Lifting Harness	1	1
Cutting Template	1	1
Work Stand	1	1
Work Bench	1	1
Pressure Band	1	1
Pressure Plate	1	1
Shipping Container	1	1
Handling Chock - Rail System	1	1
Vibration Arrangement	1	1
Supports - Ling Shaker	1	1
Slip Plates	1	1
Burst Arrangement	1	1
Burst Test Stand	1	1
Burst Fixtures	1	1
Flexib'e Bearing Test Fixture	1	1

TABLE 2-13

FINAL ASSEMBLY SPECIAL TOOLING

Tool Name	DDT & E Quantity	Total Production Quantity
Work Station Jacks	4	8
Work Platform	1	2
Rotating Dolly	8	12
Igniter Cable Bracket Installation Tool	1	1
Pyrogen Igniter Lifting Fixture	1	1
Triangular Lifting Beam	1	1

TABLE 2-14

THRUST TERMINATION SPECIAL TOOLING

Tool Name	DDT & E Quantity	Total Production Quantity
Firing Arrangement	1	1
Test Stand - Single Component	1	1
Forward Core Assembly	1	4
Pad Locating and Bending Tool	1	1
T-T Port Mold Removal Tool	1	1

TABLE 2-15

POWER SUPPLY SPECIAL TOOLING

Tool Name	DDT & E Quantity	Total Production Quantity
Checkout Stand	1	1

TABLE 2-16

GROUND TEST SPECIAL TOOLING

Tool Name	DDT & E Quantity	Total Production Quantity
Test Stand - 1 Component	1	0
Rounding Harness	3	0
Support Jacks - Segment	1	0
Firing Arrangement	1	0
Optical Alignment Tool	1	0
Lifting Beam	1	0
Rotating Dolly	2	0
Antiflight Device	1	0
APU Attach Bracket	2	0
Δ For 6 Component Stand	1	0
Cradle, Rail System	1	0

2.7 SUPPORT EQUIPMENT AND SPARES (PROJECT 7)

Under this project, Thiokol will provide the personnel, materials, services, and facilities necessary to define, design, develop, fabricate or acquire the airborne vehicle spares, ground support equipment, and GSE spares required during the DDT & E and production programs.

2.7.1 Airborne Vehicle Spares (Task 7.1)

Under this task, Thiokol will provide the personnel, material, services, and facilities to accomplish a complete spares analysis effort for the SRM Stage of the Space Shuttle. From this analysis, spares data will be generated and provided to NASA for use in planning the spares support for the DDT & E and production programs. In addition, Thiokol, after completion of the analysis effort and receiving contractual coverage, will provide adequate airborne vehicle spares to support the GTH, FTH and production programs at the operational site.

2.7.2 Ground Support Equipment (Task 7.2)

Under this task, Thiokol will provide the personnel, material, services, and facilities necessary to define, design, develop, and fabricate or acquire the ground support equipment required to deliver the SRM Stage to the launch site; receive, inspect, assemble, and checkout the SRM Stage; and accomplish integration of the SRM Stage into the Space Shuttle vehicle.

A detailed system analysis will be conducted to expand the definition of the ground support equipment requirements. The results of this analysis will be a complete list of equipment required, quantities required, and detailed design requirements for each piece of equipment.

2.7.3 GSE Spares (Task 7.3)

Under this task, Thiokol will provide the personnel, materials, services, and facilities to accomplish a complete spares analysis effort for the ground support equipment. From this analysis Thiokol will prepare provisioning lists for NASA to be used in accomplishing detailed provisioning of spares for the GSE. In addition, Thiokol will provision the spares for GSE required to support the GTH, FTH and production programs at the launch site after receipt of contractual coverage.

2.8 FLIGHT TEST SUPPORT PROJECT 8.0

Inplant support of the flight test and production programs at Kennedy Space Center will consist of generating and providing all flight data necessary to allow detailed flight planning at the launch site. These data consist of range safety data inputs to the Range Safety Manuals; mass properties report to the field site; motor performance data for each motor delivered for the flight programs; and detailed operating procedures input for the flight test directive.

Data for the Range Safety Manual will include information on the design characteristics of the pressure systems and ordnance systems. The pressure systems include the motor case, nozzle, and auxiliary power unit. The data to be provided on the pressure systems include operating pressure levels, design safety factors, and operating fluids. The ordnance systems include the motor S & A device, thrust termination S & A device and linear shaped charges; the staging motor propellant and S & A device, motor igniter, and booster pellets; and the Pyrogen igniter and motor propellants. Data on these ordnance systems will include the results of explosive hazard classification testing in accordance with the requirements of AFTO-11A-1-47, electrical and manual safing and arming procedures for the S & A devices, exhaust products chemical composition for the Pyrogen igniter and motor propellants, and the ordnance characteristics of the linear shaped charges.

Flight Program mass properties input will include the Mass Properties Predicted Weight Report; Mass Properties Actual Weight Report; Mass Properties Actual Weight Report, Missile; and the Mass Properties Post Launch Report. The Mass Properties Predicted Weight Report will include a reference station diagram, mass fraction prediction, sequential mass properties, and a list of expenditures. The Mass Properties Actual Weight Report will include the same data as the Mass Properties Predicted Weight Reports, except that the data will be actual for a specific configuration and motor. The Mass Properties Actual Weight Report, Missile (to be prepared by field site personnel) will contain only variances from the Mass Properties Actual Weight Report. The Mass Properties Post Launch Report will contain the variances from the Mass Properties Actual Weight Report, Missile.

The Motor Performance Data Report, to be supplied for each flight motor, will provide performance predictions for the specific motor supplied. These data will be presented as deviations from the baseline solid rocket motor performance data where such deviations exist.

Input for the Flight Directive generally will be a one time input covering the complete receiving and inspection requirements, motor handling procedures, motor assembly procedures, and detailed operating procedures. These data will be kept up to date, with change information provided as required. Any variations peculiar to a specific motor will be identified as such and should be used one time only, unless a subsequent input makes the data applicable to all motors.

The data from the flight tests and production flights will be transmitted to the Wasatch Division where a cursory analysis will be performed in support of the T + 10 day quick-look report. Inputs will be provided to the Thiokol site personnel, who, in turn, will prepare the Thiokol input to the quick-look report. The complete analysis of the flight data will be performed, and the T + 45 day final report for each flight will be prepared. This report will contain reduced data, the results of analyses performed, and Thiokol conclusions and recommendations.

The Final Test Series Summary Report for the flight test programs at Kennedy Space Center will be prepared at the Wasatch Division and will be submitted 60 days after the last FTH flight.

2.9 OPERATION SUPPORT (PROJECT 9)

Under this project, Thiokol will provide the necessary personnel, materials, facilities, and services to provide operations support both at Thiokol during the manufacturing of the SRM Stage and at the launch site in support of the erection, assembly, and checkout of the SRM Stages.

2.9.1 Thiokol Operations Support (Task 9.1)

Under this task Thiokol will provide the necessary personnel, materials, services, and facilities for operations support during the manufacture of SRM Stages. This effort encompasses the following functions within the Operations Directorate.

1. Manufacturing Engineering
2. Manufacturing Control
3. Works Engineering
4. Industrial Engineering
5. Quality Control Inspection
6. Quality Administration
7. Quality Audit
8. Quality Control Engineering
9. Test
10. Metrology

2.9.1.1 Manufacturing Engineering

Manufacturing Engineering is responsible for the management of the Space Shuttle Program within the Manufacturing Division. In carrying out this basic responsibility, Manufacturing Engineering provides technical direction to organizational elements of the Manufacturing Division; conceives, prepares and maintains the Manufacturing Plan; establishes component and raw material requirements and initiates procurement; establishes the need and design criteria for new or modified

equipment and facilities, and initiates design and fabrication activities; develops and prepares planning documents and process instructions; provides technical liaison with the shop; provides program coordination with organizations outside the Manufacturing Division; monitors and controls manufacturing progress and costs; represents the Manufacturing Division as a member of the Program Team and the Change Control Board; and prepares and/or directs the preparation of the manufacturing plans, technical writeups, and estimates for proposals; establishes the need and design criteria for new or modified special tooling and initiates design and fabrication activities; and approves all completed design drawings.

2.9.1.2 Manufacturing Control

This organization is comprised of three major sections: Material Control, Material Handling and Dispatch, and Scheduling and Work Control.

2.9.1.2.1 Material Control

Material Control is charged with the responsibility of ordering and maintaining accountability of raw materials, components, parts, and inhouse fabricated components; assures that Manufacturing Planning is initiated into the system, and coordinates with Procurement and processes all requisition paperwork.

2.9.1.2.2 Material Handling and Dispatch

Material Handling and Dispatch is functionally responsible for physically receiving and handling all incoming components, parts, raw materials, and associated hardware and is responsible for maintaining the stores for the Wasatch Division including storage and issuance of materials. Material Handling and Dispatch also is charged with the responsibility of packaging and processing all shipments from Wasatch; initiating inhouse fabrication orders, including detail schedules and attrition factors in accordance with Master Schedules, Program Bill-of-Materials, and Shop Travelers; providing dispatch functions for the Operations Directorate and to other Wasatch organizations as required; assuring that operations are performed in an expeditious manner, and assure compliance to schedule; managing the transportation function for movement of raw materials, components, parts and people; and preparing status reports, shortage reports, establish priorities and maintain program visibility.

2.9.1.2.3 Scheduling and Work Control

Scheduling and Work Control is charged with the responsibility of preparing, securing approval, maintaining, distributing and reporting status against Program Master Schedules; preparing composite Division Schedules for short term and long term planning exercises; maintaining a Divisionwide view of scheduled usage of mixing, casting, curing and testing facilities, and resolving any individual program

schedule conflicts in their intended use; maintaining the Operations Directorate labor work order release system; preparing, tracking, and continuing maintenance of direct and indirect labor budgets associated with the indirect material budget; contract completion estimates; earned value system maintenance and creation and maintenance of required status reporting systems; and creation, review, and analysis of written administrative procedures, manpower analysis and forecasting.

2.9.1.3 Works Engineering

Works Engineering is responsible for monitoring and controlling facility acquisition, use, and disposition to assure prompt availability of required facilities; trouble-shooting and resolving manufacturing process problems; scaling up and implementing developed manufacturing processes; developing process equipment as required to resolve problems; providing process technical support for manufacturing operations; and directing initiation and implementation of Raw Material Handling and Storage Manual, Master Batch Card Files, and Inplant Handling Manual.

Works Engineering also provides the engineering effort necessary to design tools; prepare finished drawings or specifications; perform fabrication liaison and design changes and assists in tool proofing; provides configuration control of tooling; monitor and control tool costs; operates the control tool stores warehouse and maintains tool location and use control; and maintains all tooling records.

Works Engineering is responsible for tool sustenance. Special tooling sustenance is the labor and materials required to maintain tooling in an "as new" condition for the life of the program, replacing tools as required and modifying tools for process improvements. Included is configuration management, records keeping, design modification, and periodic inspection to verify tool configuration.

2.9.1.4 Industrial Engineering

The Industrial Engineering organization reports to the Director of the Operations Directorate and accomplishes planning, control, coordination and administration necessary to support motor production and delivery; provides performance status and analysis reports to management; analyzes and reports Operations manpower efficiency and performance weekly and monthly to apprise management of progress, trends, and problems concerned with labor and material expenditures; implements methods of work measurement through work standards for all measurable operations; provides continuing effort to improve manufacturing techniques and efficiency and updating of measurable work standards; performs special studies as requested; and prepares and maintains organization budgets for measured work scope.

2.9.1.5 Quality Control Inspection

The management level personnel in inspection, i.e., foremen and above are generally considered support personnel. They perform management functions directly related to the program but not relatable to a specific motor. Their effort includes inspection planning, personnel assignment, and documentation review.

2.9.1.6 Quality Administration

The budgeting and overall planning for the Quality Function is performed by Quality Administration. In addition, personnel certification records and quality assurance stamp records are maintained.

2.9.1.7 Quality Audit

A system of continual audit of all quality functions is maintained and administered to assure compliance with all inhouse and customer quality requirements.

2.9.1.8 Quality Control Engineering

All quality engineering applicable to the program is performed by Quality Control Engineering. This includes detailed analysis of all engineering design with a signoff responsibility; preparation of Inspection Plans; statistical analyses and control; nondestructive test planning and control; definition of quality training requirements; quality representation on the Material Review Board; vendor control; and representation of Quality Assurance on the program team.

2.9.1.9 Test

The support functions provided by Test include instrumentation and gage calibration and photograph support for the program.

2.9.1.10 Metrology

Metrology provides for calibration of all measuring devices with certification to National Bureau of Standards requirements. In addition, all tool certification is performed by metrology.

2.9.2 Launch Site Operations Support (Task 9.2)

Under this task Thiokol will provide the necessary personnel, materials, and services for operations support at the launch site. The site support will consist of the necessary management, safety, quality, and training people to accomplish

the efficient planning and execution of all aspects of the receiving assembly and checkout of the SRM Stage and the integration of the SRM Stage into the Space Shuttle. The field personnel will provide Thiokol support to the test working group (TWG) and any subordinate working groups which may be organized on an ad hoc basis. The site support personnel will provide inputs directly to 24 hr TWX flight test report, and, using data provided by the home plant, will provide inputs to the 10 day quick-look report.

2.10 DATA (PROJECT 10)

The work under this task will include providing the personnel and services required to perform the Data Management effort in accordance with NASA requirements. The Data Management Organization is responsible for integrating the data effort and proposing contractor recommended changes to the Data Requirements List (DRL). This effort will be performed as follows.

1. Data Management -- The Thiokol Data Management Organization will collect, prepare, publish, and distribute data in the quantities and types designated in the DRL. The Data Management Organization will implement data management procedures in accordance with the requirements, and provide controls to prevent duplicating of data preparation. The Data Management Organization will monitor the preparation and delivery of technical reports to assure compliance with the DRL.

2. Data Requirements -- Thiokol will participate in periodic data requirement reviews of the DRL, as requested by NASA. Assistance in updating the DRL will include the identification of additional items and recommendation for deleting existing items listing on the DRL.

3. Subcontractor Vendor Data -- The Thiokol Procurement organization will include the data management requirements in all subcontracts which require the delivery of data.

2.10.1 Management Data (Task 10.1)

Under this task Thiokol will provide the management and financial data required by the DRL.

2.10.2 Engineering Data (Task 10.2)

Under this task Thiokol will provide engineering data as required by the DRL.

2.10.3 Technical Orders and Manuals (Task 10.3)

Under this task Thiokol will provide the technical orders and manuals as identified by the DRL to support the launch site operations.

2.11 RAW MATERIALS AND COMPONENT PROCUREMENT (PROJECT 20)

This project is established as a holding account against which the cost of all raw materials and components will be collected. The cost of these materials and components will be charged against the proper task at the time of usage. No Thiokol labor is to be charged to this project.

2.12 RECOVERY SYSTEM (TASK 4.4)

Under this task, Thiokol will provide the necessary personnel, services, materials, and facilities to perform the design, receiving inspection, and qualification testing of the solid rocket motor recovery system. The receiving inspection for recovery systems for the GTH, FTH, and production programs also will be performed under this task.

2.12.1 System Configuration

The recovery system will be designed to accomplish the recovery of the SRM Stage from flight after burnout, there will be two identical recovery systems in each stage, one for each SRM in the stage. Each recovery system will consist of the following components.

1. Pilot Parachute
2. Drogue Parachute
3. Main Parachute System
4. Mortars for Deployment
5. Pyrotechnic Release Device
6. Power Supply
7. Beacon System
8. Entry Spin System

The recovery system will be fabricated to the NASA approved Thiokol design disclosure.

2.12.2 Qualification Program

The qualification of the recovery system will consist of component development testing and testing of the complete system during the unmanned and manned flight test programs. Prior to the initiation of detailed component design it will be necessary to define the reentry mode of the SRM Stage after separation from the space shuttle orbiter. This will be accomplished by conducting tests of a gimbal mounted scale model in a supersonic wind tunnel and by using sounding rocket tests of scale models. Telemetry data of altitude rates and radar and/or cinetheodolite data will be recorded from these sounding rocket tests to define the reentry mode for the SRM.

Component design will be based upon the defined reentry mode of the SRM. Component testing will consist of the following:

2.12.2.1 Despin Drogue Deployment

To assure that the drogue chute will despin the rocket case and to evaluate

the dynamic loads on that chute, transonic wind tunnel testing at either AEDC, or at NASA Langley Field will be required. A gimbal mounted scale model with a scale drogue chute will be tested. Wind tunnel tests for Mach numbers of 1.2 to 0.8 will be required.

After the wind tunnel tests have been conducted and the drogue system hardware has been designed, scale drop tests are necessary. A one-third size drogue chute and suspended weight model will be dropped from a B-52 aircraft at the Joint Parachute Test Facility Auxiliary Landing Field at El Centro, California. These tests will require tensiometers on the drogue bridle load points and accelerometers on the suspended weight body. In addition the facility cinetheodolite will be required.

2.12.2.2 Main Parachute

Because of the size of the main parachute system, scaling of wind tunnel size models is thought to be undesirable. Drop testing of one-third scale models including the clusters of six parachutes will be required. These tests will evaluate the cluster aerodynamic deployment, dynamic loads, and descent rates. In addition a full scale test of a single parachute with a one-sixth suspension weight will be required. This test will be required for parachute structural integrity validation. Static pull test of the parachute cloth will be performed and seam and joint stitching, pocket band construction, and reefing joint ties will be static pull tested.

2.12.2.3 Mortar for Deployment

Subsystem testing of the pilot chute mortar will be required to evaluate breech pressures, power unit throat erosion rates, and muzzle exit velocities. These tests will be conducted on the ground at subcontractor test facility.

2.12.2.4 Pilot Parachute

The design testing of the pilot chute will be conducted on a test vehicle, either a sled or a high speed aircraft.

In addition to the load and aerodynamic testing described above, all system components will be subjected to temperature, humidity and vibration environmental testing.

The main and drogue parachutes will be tested in B-52 drop tests with increasing loads. The greater parachute loads will be achieved by increased deployment velocities and suspended weights. These tests should establish the variation in decelerator performance and design system safety margin.

The structural integrity of the entry system spin fin will be tested by static aircraft type, multiple point loads procedure.

The mortars, pyrotechnic release devices, power supply and beacon system will be tested for a complete matrix of environment conditions.

Final qualification of the complete recovery system will be accomplished describing the unmanned and manned flight test program.

2.12.3 Qualification Completion

The recovery system qualification will be considered complete upon successful completion of the model and full size component testing and upon successful recovery of an SRM Stage during the Space Shuttle Vehicle Flight Test Program.

2.12.4 Program Recovery Systems

Recovery systems for the production program will be fabricated, received and inspected under this task using the tooling, processes and procedures developed during the qualification and FTH programs.

3.0 MANUFACTURING PLAN

This Manufacturing Plan describes the Primary and Supporting Inplant Flows, the processes selected during the study program for both the DDT & E and Production Programs, and the reasons for each selection. The manufacturing and inspection processes selected have been proven during fabrication of solid propellant rocket motors of the same and similar sizes. The inspection steps selected were established to verify quality at the conclusion of each major manufacturing operation. In addition, quality is verified at intermediate points to reduce the additional cost and delays that would result from defects discovered at a later step in the process. All quality inspection steps take into account the requirements of a manrated system. Many weighing, mixing, and curing operations are monitored completely to assure quality in these operations, which cannot be verified by subsequent inspection.

3.1 PRIMARY INPLANT FLOW

The transportation of case segments from the vendor to the Utah facility will be by rail and by commercial low-bed trailer from railhead to plantsite. The use of a specially designed trailer is not necessary, since the dimensions and weight of the cases are within available commercial capability.

Unloading, at the storage pad area, will be accomplished using slings and a mobile crane. All subsequent inprocess handling of the unloaded segments will be performed using a pneumatic handling harness. This harness employs inflatable bladders retained within an exterior support structure, which, when pressurized, expands within the support to exert a gripping force on the encircled case section. This gripping force is adequate for lifting and inverting the cases. This handling concept has been chosen since it provides for all the necessary handling operations without harness rings attached to the case joints. This handling concept is currently being used for both empty and loaded Stage III Minuteman cases. After the segments are loaded, they will be removed from the casting pit using a handling harness and will be positioned on a rotator. The harness will be removed and all subsequent handling will be accomplished with the loaded segment positioned on the rotator.

Included in this section also is a discussion of the process for refurbishment of the case and nozzle.

The following flow charts, Figures 3-1, 3-2 and 3-3, depict the flow of the main motor segments and supporting component parts through the plant.

THIS SPACE INTENTIONALLY LEFT BLANK

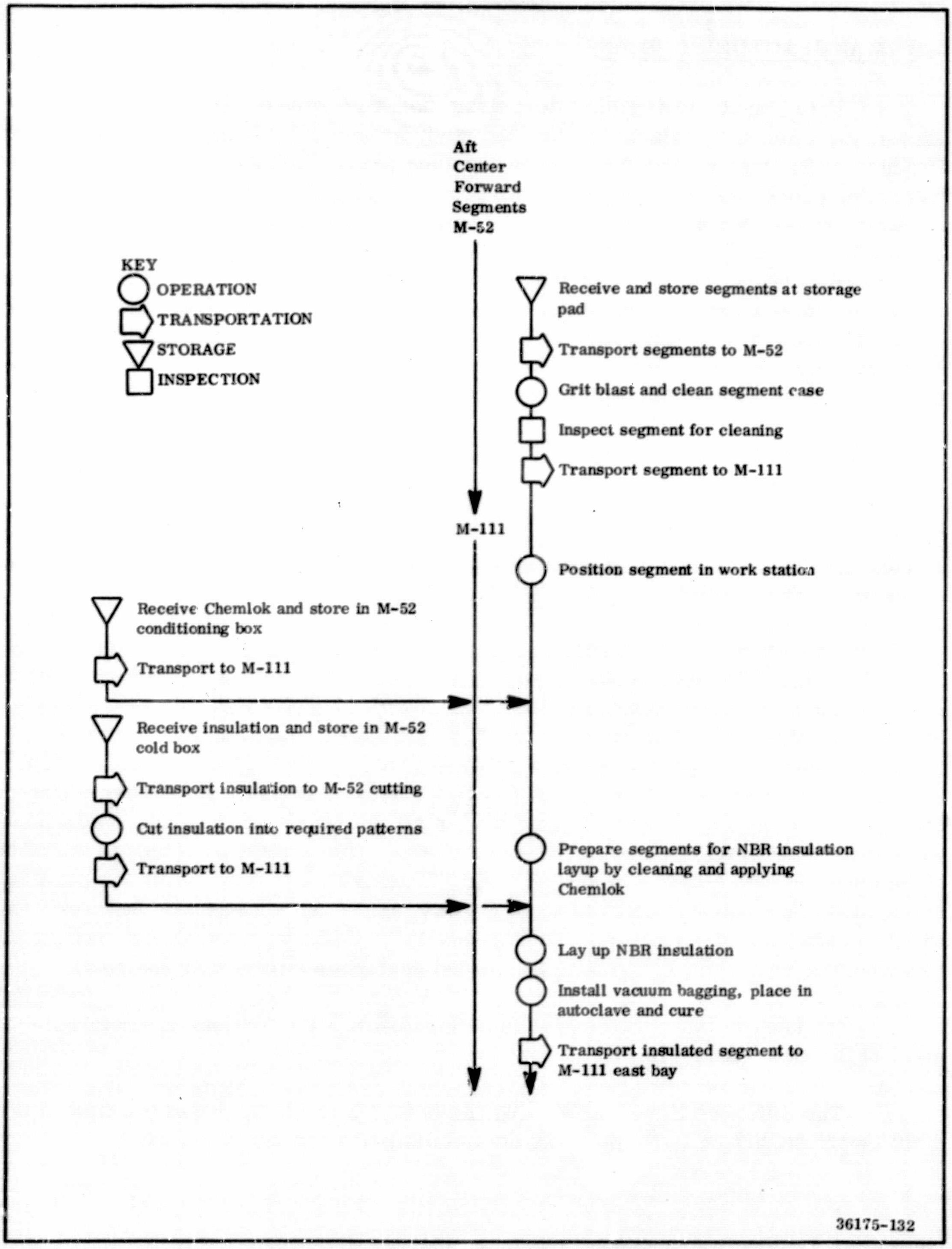


Figure 3-1. Manufacturing Process Flow Chart

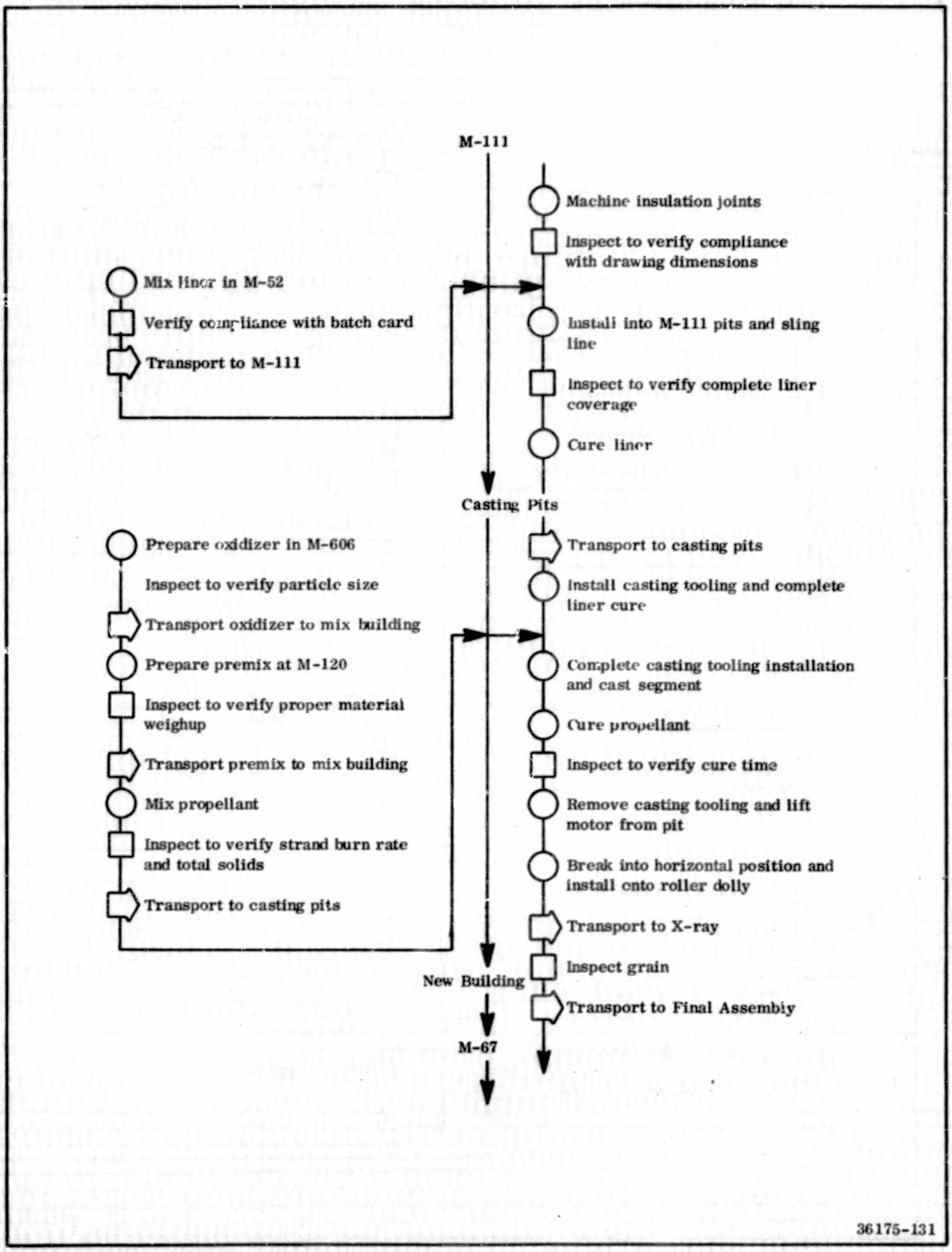


Figure 3-1. Manufacturing Process Flow Chart (Cont)

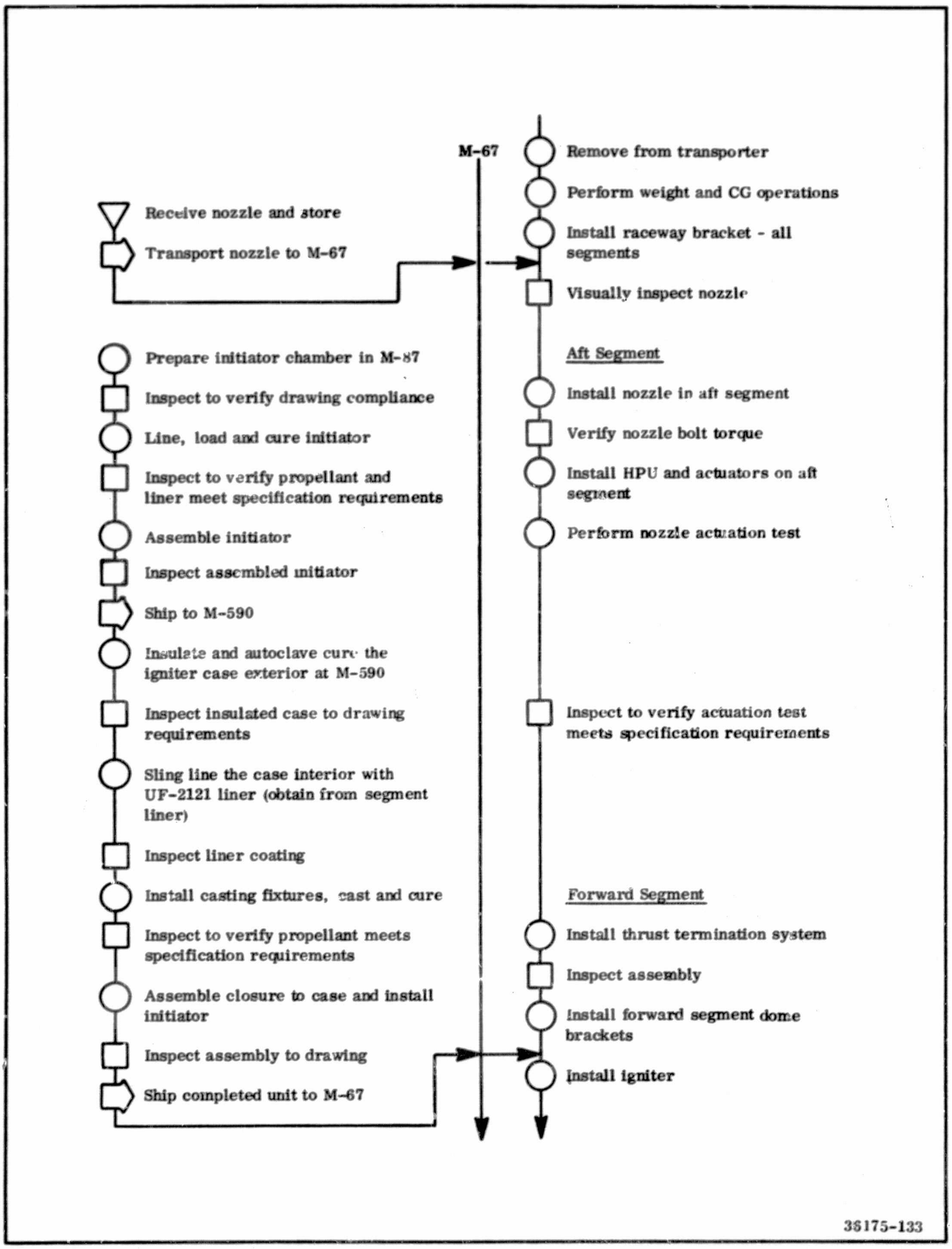


Figure 3-1. Manufacturing Process Flow Chart (Cont)

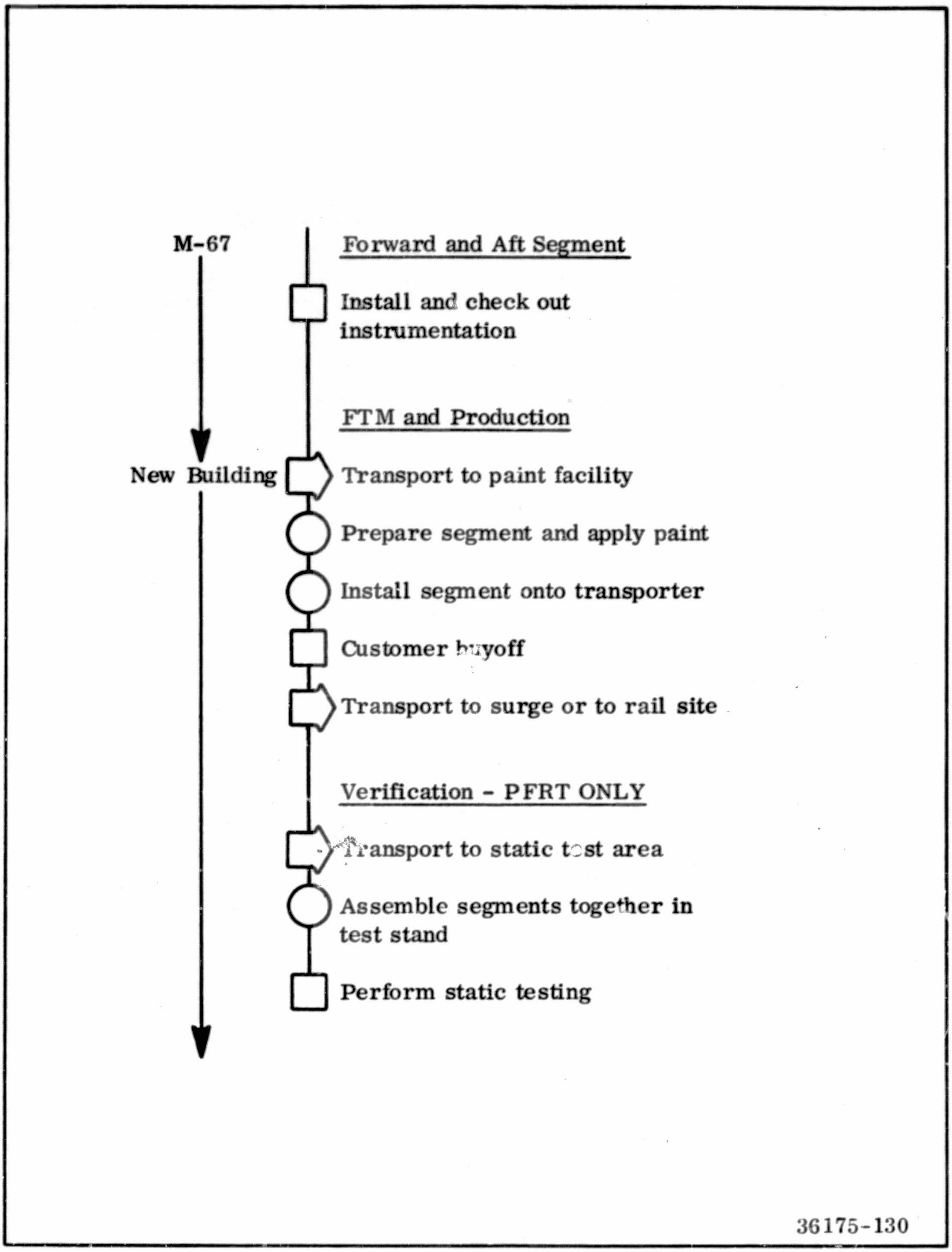


Figure 3-1. Manufacturing Process Flow Chart (Cont)

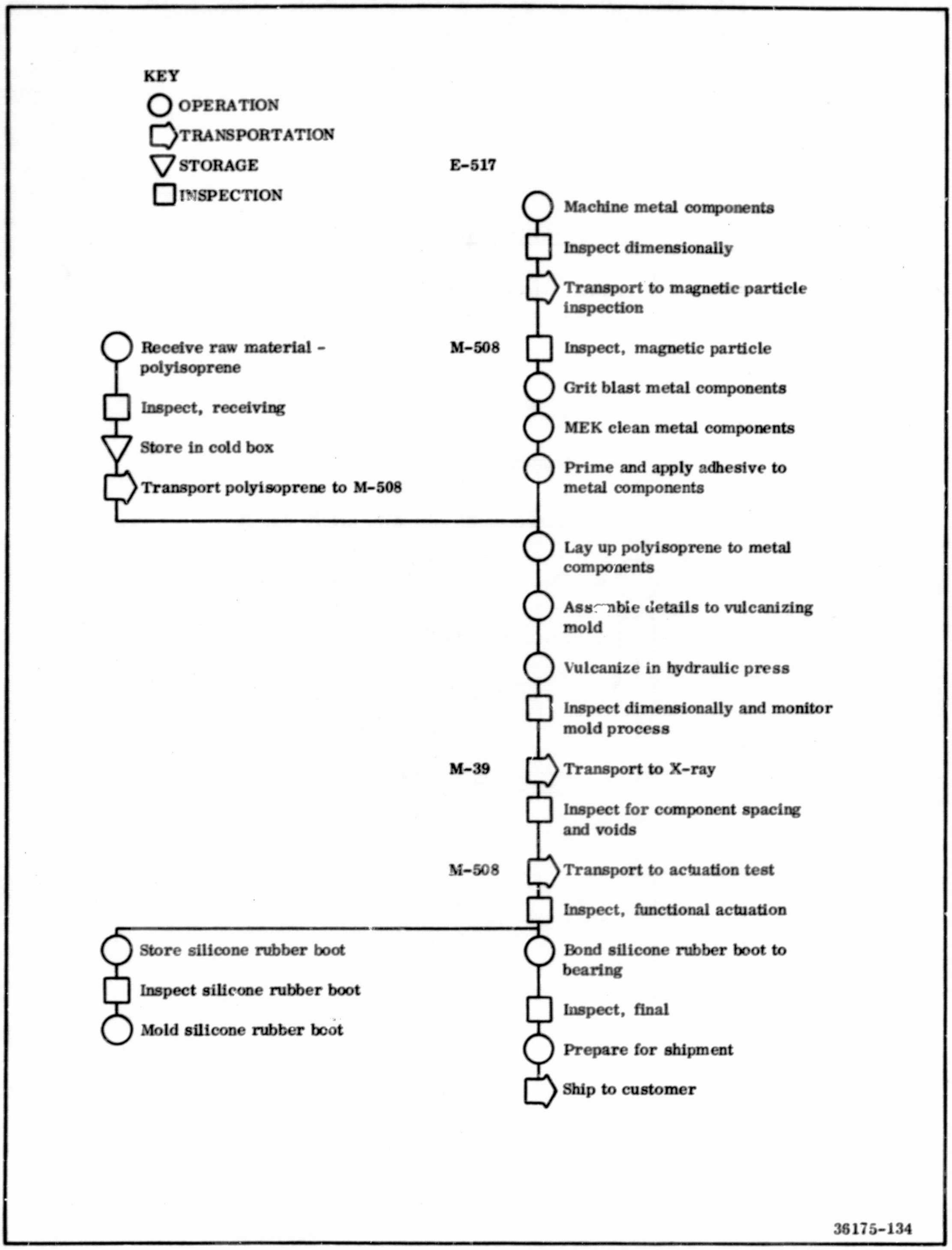


Figure 3-2. Nozzle Flexible Bearing Manufacture

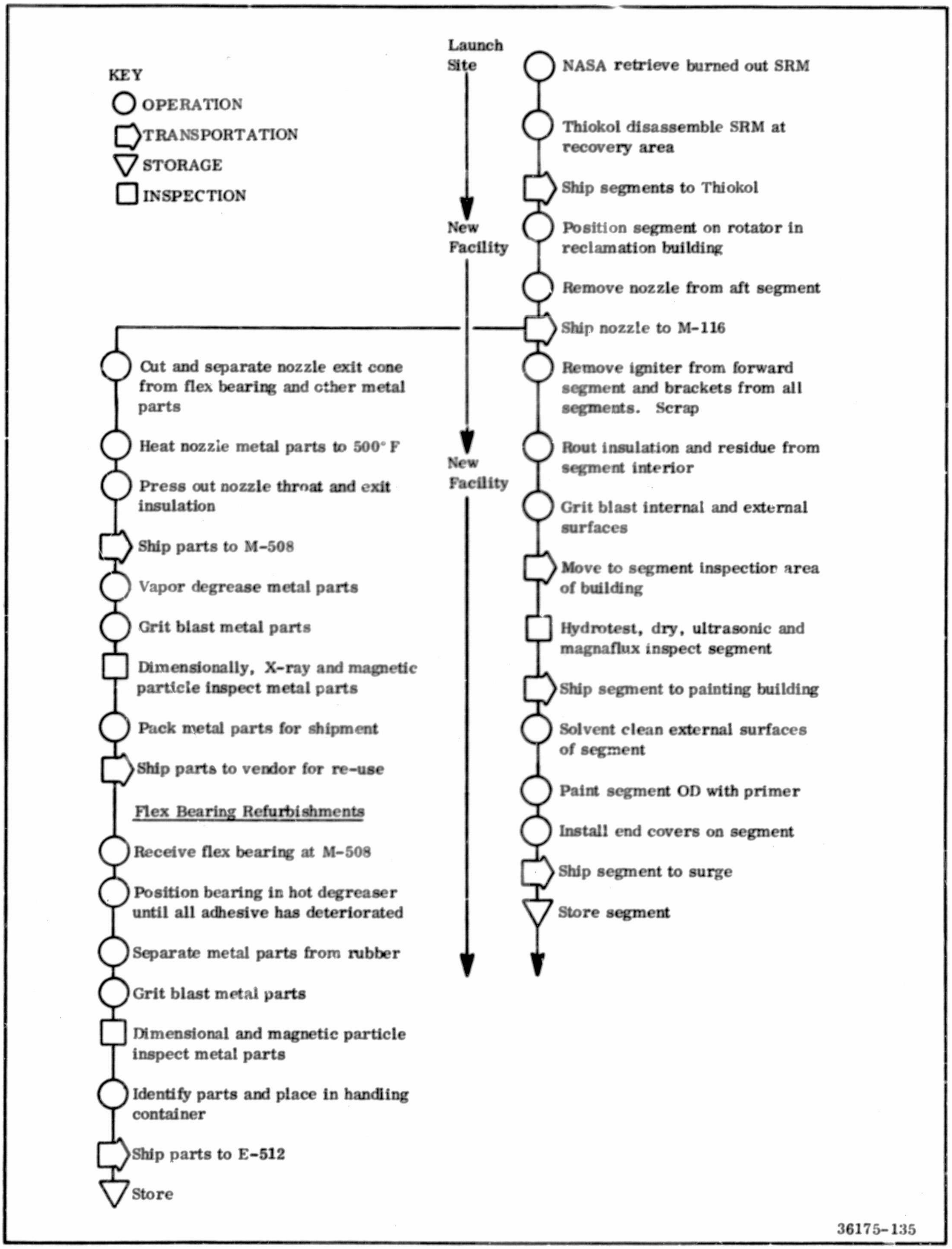


Figure 3-3. SRM Refurbishment

3.1.1 Start Segment to Lining

The interior of each segment will be completely cleaned prior to installation of the insulation. This will be accomplished by grit blasting the internal surfaces with zirconium silicate and subsequently solvent cleaning using trichloroethylene. The solvent cleaning will be accomplished by spraying trichloroethylene onto the interior segment surfaces while the segment is positioned over a conventional degreaser. This solvent cleaning technique has been used extensively on various sizes of rocket motor cases including the Stage I Minuteman case, and has proven to be a simple, direct, and economical cleaning technique.

The installation of the rubber insulation in the cases will be a semimechanized layup operation of the unvulcanized material, followed by vulcanization in place. This technique has been selected rather than the prevulcanization, bonded-in-place technique, due to its inherent economy and quality. Production of prevulcanized insulation parts for large motors has proven to be expensive due to dimensions and the cleanness of the surface necessary to assure quality bonds when installed in the case. Also, the case dimensional variations can cause problems, with void areas in the glue line, and proper location of the insulation part within the metal part. These problems are all eliminated by the use of the uncured rubber layup and vulcanization-in-place technique. This technique has been demonstrated by Thiokol on various size cases including 156 in. diameter size.

The insulation pieces and calendered stock are then semimechanically laid in position and pressed firmly by hand rolling or tamping. This assures intimate contact of the insulation with the case, without entrapment of voids. The required insulation thickness and profiles are obtained by the application of the proper number of layers of insulation in this cutting-activation-positioning sequence. The relief flaps are formed as an integral part of the insulation layup, being separated from the backup insulation by a thin layer of a mold release film. At the joint areas, mold rings are used to form the precise insulation dimensions of the unvulcanized materials. With this technique, molding of NBR insulation to precise tolerances has been successfully accomplished on several sizes of rocket motor cases.

The insulation installation operation will be accomplished with the segment positioned on a rotator in the insulation layup bay. Interior segment surfaces to which rubber insulation is to be vulcanized will first be prepared by spray coating with a Chemlok primer system. NBR insulation laid up in the dome sections of the aft and forward segments will be precut to specified dimensions. The cylindrical portions of all segments will be insulated using NBR roll stock of varying lengths. Surfaces of the NBR will be activated using methyl-ethyl-ketone (MEK).

When all the required insulation material has been properly positioned, reusable vacuum bagging is positioned over the insulation and sealed against the case walls or mold rings. The case will be placed in an autoclave. The vacuum system

provides for positioning control of the insulation and removal of any volatiles released during vulcanization. The autoclave provides the 100 psia pressure, using air as a pressurization medium, to achieve the required insulation cured density. The autoclave also provides the heat for vulcanization. The cure cycle chosen has been used for insulation processed on previous successfully tested motors, and complies with the insulation manufacturer's recommendations.

After the vulcanization operation, the case will be removed from the autoclave, and the vacuum bagging and mold rings are removed. The insulation will be completely inspected for dimensional acceptability. Following acceptance by the inspection, the segment split flap will be secured in preparation for liner application.

During the development program the insulation in the joint areas on the first 15 segments will be molded oversize and the joint will subsequently be routed to the final configuration. During the first 15 segments the cure shrinkage of the joint will be established thus allowing all subsequent segment joints to be net molded.

The insulated case then will be completely recleaned on the interior, using the hand-scrubbing techniques, with MEK solvent used for the insulation surfaces, and trichloroethylene solvent used for the metal surfaces.

3.1.2 Segment Lining

The cylindrical and dome portions of each segment will be lined using the sling lining technique. This technique has been proven during several years on approximately 2,000 Stage I Minuteman motors, and on numerous other motors from 15 to 156 in. in diameter. The UF-2121 liner material is viscous, tenacious, and extremely difficult to spray. However, development of the specialized equipment and procedures of the slinging technique facilitate a straightforward, high quality application. In this qualified technique, the liner material is pumped into a hollow, 9 in. diameter disc which is rotating at 7,000 to 9,000 rpm. The liner is physically impelled by centrifugal force, through 0.060 in. wide peripheral slits in the disc. It emerges from these slits as droplets with high velocity which impact the case surface at approximately a right angle, and provide intimate surface contact and wetting action while flattening against the surface.

The sling liner equipment causes the disc to traverse the case length automatically with several passes, while applying the required quantity of liner. This multiple pass application assures uniform distribution of the liner material. This method of application deaerates the liner material as it is applied, and produces a continuous void free liner. The liner application process controls the weight of the liner to within 0.1 percent by monitoring the weight of lining material delivered to the slinger disc.

The completed liner application then will be cured for 29 hr at 135°F while positioned in the liner cure pit. This cure has been selected on the basis of studies which demonstrate that the liner is sufficiently cured to prevent bubbling under vacuum, and also that a cure time of this degree has no detrimental effect on the bond strength of rubber to liner to propellant systems.

Following the liner cure, the weight of the insulated and lined case will be determined. This weighing facilitates the later determination of net propellant weight. The case then is loaded onto an inplant trailer and transported to the casting pit. The case interior will be completely protected during transportation with dusttight, weatherproof covers to prevent contamination of the liner surface.

3.1.3 Segment Loading

The objective of the propellant casting operation is to form a void free propellant grain to exacting dimensional tolerances from a viscous slurry containing a very high proportion of solids. Special handling and safety precautions during processing are necessary because of the flammable characteristics of the material. The basic method of deaeration, casting, and forming which will be used on the Space Shuttle Booster has been used extensively and successfully on many sizes of rocket motors, including 156 in. diameter motors that were successfully loaded and fired. The method is commonly referred to as vacuum casting. This technique allows the propellant to form the motor grain under evacuated conditions, thus eliminating the tendency for air entrapment. The technique emphasizes simplicity, which inherently improves the safety of the operation and contributes to the consistent quality of the propellant grains.

When a center or aft segment arrives at the casting pit, it will be lifted from the rotating handling dolly using a pneumatic harness and gantry crane. The segment then will be lowered into the casting pit and positioned on and secured to the casting base plate. This base plate is located on the casting stands, and thus provides complete support of the segment for the propellant casting curing operation. It also forms a mold for propellant grain surface providing exact grain dimensional requirements and provides core centering.

When a forward segment arrives at the casting pit, it will be lifted from the rotating handling dolly on which it was transported using a pneumatic harness and gantry crane. It then will be lowered into a casting pit, positioned on and secured to the casting stands.

These casting pits operate in reverse of the conventional assembly line concept by maintaining a stationary product serviced by portable processes and equipment. This concept, because of the size and nature of the product and the special safety considerations for the propellant, results in considerable cost and cycle time savings. Motor handling is minimized, with only installation in and removal from the casting pit required. Each pit is equipped with heating and air circulation equipment to control and maintain uniform temperatures during the entire loading and curing cycle.

After positioning the cases in the proper pit, portions of the casting tooling are installed. The aft grain propellant mold will be installed onto the case and secured in place. The core will be installed and aligned radially and longitudinally by a pilot hole in the casting base plate and a centering device indexing from the aft grain propellant mold. This assures the propellant grain cavity will be properly located after the propellant has been cast and cured. After the casting tooling has been properly installed, the pit lids will be lowered and the liner cure completed at 135°F for eight additional hours. Upon completion of liner cure, the vacuum chamber will be simply positioned over the casting tooling, resulting in a closed chamber which can be readily evacuated for the propellant casting operation. The propellant hopper assembly consisting of a support stand and two transfer hoppers will be located on the vacuum chamber and connected through a pneumatically actuated butterfly valve to a "slit" plate mounted in the dome casting opening. This slit plate contains numerous parallel slits of a controlled width, and is exposed on the bottom to the evacuated segment interior.

During the casting operation, the propellant, after acceptance by Quality Assurance, is received at the casting house, in the as-mixed condition, in the vertical mixer mixing bowl. This propellant then is emptied by inverting the bowl into the casting hopper.

The propellant is slowly forced by the pressure differential from the hopper, through the valve and tubing, to and through the slit plate. The propellant emerges from the slits in parallel ribbons, which are exposed to the low pressure evacuated interior. Any entrapped air in the propellant is immediately flashed out and removed from the thin propellant ribbons as they fall into the segment. This process is called "deaeration" and assures a void free, high quality propellant grain. The deaerated propellant falls freely into the case interior and gradually fills the case to the proper level. The complete casting operation requires repetition of the dumping operation of the mixing bowls into the casting hopper until the proper amount has been cast. After the propellant has been cast to the aft grain mold and sufficiently into the grain mold sleeve, the vacuum in the chamber is gradually reduced. The propellant level is closely monitored during this operation and propellant added as required to maintain the proper level. The casting hopper and vacuum dome then is removed and the propellant level troweled and adjusted if necessary to assure it is within specified tolerances.

Process inspection personnel will monitor the entire loading operation to insure proper installation of casting tools, compliance with processing procedures and limits, nd to provide verification of all recorded data. Representative samples of the propellant will be obtained by the inspector and cured concurrently with the motor for subsequent physical property verification tests. Standard JANNAF tensile specimens will be cut from these samples, temperature conditioned, and tested to failure on an Instron Tensile Tester. From the recorded data, the propellant modulus, stress, and strain properties are calculated. The propellant density and Shore A hardness also will be determined. These data will be compared with specification

limits to insure propellant acceptance. If the data indicate a trend toward tolerance limits, the formulation of subsequent propellant mixes will be adjusted to compensate. In this manner, a rigid control of propellant physical properties will be maintained within specification limits.

After completion of the casting operations, the casting house will be removed from the pit and the pit lid is put in place for the propellant cure. The propellant cure will be at 135° $\pm$ 5° F for 96 hours. The curing will be continually monitored from the control room at M-32, which contains the controller-recorder. Following this cure, the pit lid will be lifted to allow introduction of ambient air and the heat input will be turned off. The loaded case will be allowed to cool with the circulation system moving conditioned temperature air for a minimum of 48 hours. After this initial cooling the core will be "popped" free using a conventional hydraulic jack system, then lifted from the loaded case with the gantry crane.

After these loading operations are completed, the aft grain propellant mold will be removed from the loaded case, using the gantry crane. Then using the aft handling ring harness, the loaded case will be lifted off the casting base or casting stand and out of the pit with the gantry crane.

The loaded case then will be placed into the forward harness ring and the side beams connecting the forward and aft harness rings attached. The harnessed case will be positioned onto a hydraulic controlled breakover fixture and lowered into the horizontal position. The harnessed case then will be lifted by a four point lifting beam and positioned onto a horizontal handling and rotating dolly where it remains throughout most of the remaining operations. The handling harness then will be removed from the loaded case.

3.1.4 X-Ray, Final Assembly, Paint, and Ship

The loaded segments will be shipped to the X-ray facility where the propellant grain will be 100% inspected radiographically for defects. At this time the segments are transported to the final assembly building.

The loaded segment and rotator assembly will be unloaded in the final assembly work station by lifting the rotator and segment above the transporter bed using a hydraulic jack station arrangement. The transporter then will be pulled out of the work station and the rotator and segment lowered to the floor level.

At this point the loaded segment will be weighed and weight and center of gravity established using a jack station and load cells.

The remaining operations that will be performed at this work station include the installation of the raceway and dome brackets, assembly of the igniter/initiator to the forward segment, and assembly and checkout of the nozzle to the aft segment. These operations, with attendant cure cycles, will permit planned concurrency of operations and maximum utilization of the crew and facility. For example, the igniter/initiator assembly will be installed in the forward closure while the raceway bracket bonding material cures.

The installation of the raceway and dome brackets will be a simple bonding operation, with the attachment tooling providing for automatic location of the brackets with respect to the joints or skirts, and application of pressure to press the brackets against the case surface.

The installation of the igniter assembly in the forward closure is a simple position/bolting operation. The igniter assembly will be received at the final assembly work station, in the storage container, positioned with the attach flange at the top. The lifting device will be attached and, using the bridge crane, the igniter assembly is lifted from the container and installed into the forward segment igniter port. Bolting and lockwiring then are performed.

The segment still positioned on the rotator will be transported to the paint facility and unloaded using the same method as in the final assembly work station.

Painting will be performed by spray technique. The surface of the first primer coat, applied by the case vendor, will be hand scrubbed with clean cloths soaked in trichloroethylene solvent. The final paint coating then will be applied and dried at least one hour prior to further operations involving contact with the painted surface.

After completion of the assembly and painting operations, the segment will be presented for physical inspection by the resident Quality Control representative of the customer.

The accepted segments will be stored on the loaded segment rotator on a storage pad. A portable enclosure with the capability of maintaining a temperature of 60° to 100° F will be positioned over each segment.

Movement from the storage pad to the rail siding will also be on the inplant low bed trailer. Loading and unloading of the segments at the storage pad will be accomplished using a portable jack arrangement.

The transloading operation at the rail siding will be performed with a 200-ton bridge crane. The segment simply will be lifted from the low bed trailer using the bridge crane and a loaded segment Pneuma-Grip, and will be positioned on the railcar.

After transloading and tiedown of the required number of segments has been completed, the loaded rail cars will be turned over to the control of the commercial carrier.

3.1.5 Refurbishment of Fired SRM Segments

Burned out booster motors will be retrieved, disassembled and transported to Thiokol. All live ordnance components (thrust termination charges, etc) will be removed prior to shipment to Thiokol. Segments will be received inplant on a low bed transporter and will be stored on outside pads until scheduled for refurbishment.

After removal of the nozzle and Pyrogen igniter from the aft and forward segments, the process of refurbishment is basically the same for all segments. All handling of the fired segments in the refurbishment facility will be accomplished using an empty segment Pneuma-Grip fixture. The remaining insulation in the segment will be removed using a high speed servocontrolled router. After insulation removal the segment will be moved to the grit blast bay and both interior and exterior surfaces will be grit blasted with zirconium silicate to remove any remaining insulation residue. Each segment then will be hydrostatic, ultrasonic, and magnaflux inspected for conformance to Engineering requirements.

The accepted segments will then be transported to the painting building where the cleaning of the OD and application of paint primer will be accomplished. End covers will be installed on the segments and the segments will be stored on surge pads until scheduled for reprocessing.

3.1.6 Nozzle Joint Refurbishment

The metal parts of the nozzle joints will be reclaimed using the same process that has proven successful on the Poseidon C3 program. After removal of the flex joint from the nozzle, it will be placed in a trichloroethylene degreaser tank to deteriorate the adhesive bonding the silicone rubber boot and elastomer to the metal components. The boot and elastomer then are separated from the metal parts.

The metal parts are grit blasted to remove Chemlok primer and blend out any surface irregularities.

Quality Control personnel will perform a magnetic particle and a dimensional inspection to verify parts are acceptable to blueprint and all specifications. After acceptance, parts will be identified and placed in stores for use in refabricating a replacement nozzle joint.

3.2 SUPPORTING INPLANT FLOW

Major inplant efforts to support the primary segment flow which has been described previously are described in this section. These major support areas are as follows.

Liner Manufacture (3.2.1)
Propellant Manufacture (3.2.2)
Igniter and Initiator Manufacture (3.2.3)
Nozzle Flex Bearing Manufacture (3.2.4)
Test Operations (3.2.5)

3.2.1 Liner Manufacture

Each of the liner ingredients are categorized into material lots and are further segregated by evaluation numbers. Each evaluation then will be mixed to the proper formulation and the critical physical properties verified. Adhesion, peel, and lap shear samples will be cured and tested to failure. The resultant data will be compared with the specification limits to verify conformance.

For production use, the ingredients will be drawn from accepted lots and removed from controlled storage conditions. A 75 gal planetary motion vertical mixer will be used to blend the ingredients. The liquid ingredients will be added in the proper proportions and blended prior to adding the solid constituents. The solid materials then will be uniformly and slowly added to the liquids and the proper mix cycle completed to thoroughly blend the materials.

Verification of all weights, of mix viscosity, mix time and all other pertinent processing parameters are documented by Quality Control personnel. Tight controls on all aspects of liner mixing will be implemented to assure high quality liner.

3.2.2 SRM Propellant Manufacture

The proportioning and mixing of the propellant materials will be performed using equipment that has been used extensively for production of motors over a wide range of sizes including 156 in. diameter motors. This equipment includes an oxidizer grinding and apportioning system that will automatically weigh the required amounts of unground and ground oxidizer and convey the material to a

mixer hopper. The grinding will be accomplished by a Mikro-Bud vertical grinder of the same type that has been used for approximately 2,000 Stage I Minuteman motors as well as for Third Stage Minuteman and Poseidon motors.

HB polymer and aluminum powder will be accurately weighed into a horizontal mixer where the aluminum powder is thoroughly wetted in the polymer. The calculated batch requirement then is weighed into the 600 gal vertical mixer bowl, the curative is added from a loss-in-weight hopper, and the premix material will be delivered in the mix bowl to the mixer station.

The mix bowl containing the required amounts of all materials, except oxidizer, will be positioned onto the vertical mixer. After the mixer is started through the automatic propellant mixing cycle the oxidizer will be remotely and automatically added at the appropriate point in the mix cycle.

This system virtually eliminates the human element, provides complete and accurate records on important aspects of the process, and assures a superior quality propellant by quality control and testing.

The inprocess control of propellant will be maintained by analyzing a sample of uncured propellant prior to casting. Total solids, an infrared spectrographic analysis, and uncured strand burning rate analysis will be conducted on individual mixes.

Three loaf samples will be cast from three mixes per segment and will be cured and tested for physical properties determination.

Three ballistic test motors will be cast from three mixes per each segment, cured, and test fired. The results of these tests will be used to verify and re-establish the baseline for inprocess batch acceptance of burning rate by uncured strands, and to make adjustment in oxidizer fraction. The inspection procedures and tests will be so constructed to provide the quality required for a manrated vehicle.

3.2.3 Igniter and Initiator Manufacture

The igniter metal case will be received from the vendor uninsulated. The exterior case surface will be prepared for NBR insulation application and vulcanization by grit blasting with zirconium silicate and solvent cleaning using MEK. A Chemlok primer system will be spray applied to the case and precut NBR insulation hand laid up to the desired thickness. During layup, the uncured NBR surfaces are activated by wiping with MEK. Mold rings are used to form the aft and forward insulation surfaces. A vacuum bag will be installed over the NBR layup and sealed at each end. The rubber will be vulcanized in an autoclave at a maximum temperature of 315°F for a period of 10 hours.

The insulated igniter case internal surfaces will be cleaned by scrubbing with MEK and cheesecloth prior to liner application. The igniter case will be lined with UF-2121 liner using a sling lining technique similar to that used for the booster segments. The liner will be cured at 135°F for 44 hr minimum.

The lined igniter case will be moved to the casting facility where the casting fixtures consisting of a casting sleeve, core guide, propellant grain mold, core, and core retainer are assembled.

Propellant will be cast into the igniter using a pressure casting system which forces the propellant into the case from the bottom opening (nozzle end) of the case. After the propellant reaches a predetermined height the casting will be terminated and the core seated and secured in place. The propellant grain will be cured for 96 hr at 135° F.

After removal of the casting fixtures, inasmuch as the propellant grain is net molded, the loaded igniters will be inspected radiographically for propellant grain defects.

After initiator adapter is assembled to the accepted igniter, it will be secured in place using bolts. The initiator then will be assembled to the adapter and secured in place using bolts. After completion and acceptance of the igniter-initiator assembly, the unit will be placed in a handling container and moved to surge, test, or to the final assembly area for installation into the loaded forward segment of the booster.

Propellant used for the igniter will be TP-H1016. This propellant formulation has been and is currently being used on the Genie motor program. All processing techniques which include raw material acceptance, formulating of raw materials, mixing, and inprocess testing of mixed propellant have been extensively used at this Division in the manufacture of TP-H1016 and other similar propellant formulations. Inprocess controls similar to those defined

for the booster propellant will be imposed on this propellant. Ingredient lot changes will be controlled through a standardization process. The ingredient lots are segregated and assigned evaluation numbers. Twenty gallon propellant mixes will be prepared using varying polymer to curing agent ratios and varying ground to unground oxidizer ratios.

From each standardization mix, ballistic test motors and uncured liquid strands will be cast to determine the characteristic burning rate of each formulation. One-half gallon propellant samples will be cast from which standard JANNAF tensile specimens will be cut and tested to determine respective physical properties. Analysis of these data will determine the optimum propellant formulation for the specific ingredient lots used.

The igniter initiator fabrication technique will be similar to that used on Third Stage Minuteman igniter.

The initiator grain is a case bonded, 16 starpoint configuration cast into a steel case. The grain will be similar in design to that of the Poseidon Stage I igniter and Third Stage Minuteman igniter which are presently being cast at the Wasatch Division. Similar tooling and casting techniques will be employed for the Pyrogen initiator. A safety and arming device will bolt onto the initiator adapter which is similar to the system used on all Minuteman motors.

The initiator will use TP-H1016 propellant from the same batch from which the igniter is cast so that separate characteristic and standardization testing will not be necessary.

3.2.4 Nozzle Flexible Bearing Manufacture

The Thiokol Chemical Corporation, Wasatch Division began work in the latter part of 1967 to develop a flexible elastomer nozzle bearing for use in the Poseidon C3 First and Second Stage Motor nozzles. The diameters of these motors are 74 in. OD with corresponding elastomer bearings of 22.5 and 22.7 inches in diameter. The development phase was completed in 1968 and production quantities of over 250 first stage and over 300 second stage bearings built thru the end of 1971. Reliability of the production bearings has been exceptionally high.

The fabrication process used to make the Poseidon C3 bearings has been followed as the proposed process to fabricate a similar elastomer bearing for the 156 in. diameter Space Shuttle Motor.

This process will begin with fabrication of the steel end rings and reinforcement shims using existing standard metal cutting facilities. The elastomer material will be polyisoprene sheet stock hand cut to strip size for assembly layup. Spacing of the elastomer will be controlled by placing spherical steel

spacers between reinforcement shims. Dimensional and process parameters will be monitored and verified by inspection throughout the entire process.

Preparation for molding will begin by grit blasting and MEK cleaning of the bonding surfaces of steel components. One coat of Chemlok 205 primer and two (2) coats of Chemlok 220 adhesive will then be sprayed on the metal components. The elastomer strips will be applied to prepared surfaces and the spherical spacers imbedded under the elastomer to retain their location during the cure cycle. All rings will be assembled to the vulcanizing mold by stacking in the proper order. The top mold section will be located and the assembled mold loaded to the vulcanizing press. Curing will be accomplished using programed temperatures and pressures. After completed bearing is removed from the mold, any flashing will be removed by hand tools. Quality Control personnel will perform necessary NDT and functional acceptance testing of the completed joint.

3.2.5 Static Test Operations

Each 156 in. diameter motor segment will be received at the test bay with rounding rings installed. The assembly fixture will utilize the pallet concept of handling the segments. The pallet will be lowered on the assembly fixture which will be capable of longitudinal, lateral, pitch, yaw, and roll movement. The first segment will be attached to the thrust adapter and all alignment adjustments will be made prior to removing the assembly fixture. The second segment will be received the same as the first, and the first joint will be made. The rounding rings of the first joint will be removed and sent to Manufacturing for placing on the third segment. Each segment will be assembled in the same manner. After the last segment is assembled in the test stand, temporary supports under the segment joints will be removed and any alignment adjustments will be made. Concurrent with the motor assembly, transducers will be installed and hooked up to the instrumentation system. Facility hydraulic power will be used to check out nozzle actuation. On the day of the test a final dry run will be conducted to check all instrumentation channels, nozzle actuation, and motor picture camera starts. Upon successful completion of the dry run the conditioning house will be removed and the nozzle hooked to the onboard hydraulic power supply. The motor then will be tested within two hours.

Post-test operations will include photographs, nozzle physical measurements, examination of the motor for any failures, and disassembly of the motor and return to the manufacturing area for detailed post-test analysis. A quick-look data meeting will be arranged for eight hours after the test, to present data from thrust, pressure, and nozzle actuation measurements. Test Bay T-24 will be modified to allow testing of a five segment 156 in. diameter motor. The modification will include a movable conditioning house that will cover the assembled motor and maintain a temperature of $80° \pm 20°F$. A new six component test stand will be installed in T-24. The test stand will provide adjustments for motor alignment. Each component load cell will be easily removed for calibration.

4.0 GENERAL TEST PLAN

4.1 SCOPE

This document establishes the Design, Development, Test and Evaluation (DDT & E) program that will be conducted on the configuration items, components, assemblies, and subsystems of the Space Shuttle Solid Rocket Motor (SRM) Stage and associated Ground Support Equipment (GSE) to demonstrate compliance with the applicable performance requirements.

This plan is based on the concept of testing only those items and components that are new, redesigned, or operate in a more severe environment than already qualified components. In support of this philosophy, the DDT & E test plan is designed to:

1. Support the SRM Stage and GSE design effort with component verification test data early in the acquisition phase of the program.

2. Qualify all unqualified flight hardware at the component level.

3. Verify the SRM propulsion subsystem design during the Design Verification Motor Firing Program.

4. Verify the qualification of the SRM propulsion subsystem for use in the Flight Test Program during the Preliminary Flight Rating Testing (PFRT) Program.

Thiokol has considered cost effectiveness (minimum cost at maximum reliability) as a primary objective throughout the study and definition of the SRM Stage. Proven component designs and technology are used in all possible areas to preclude costly hardware, manpower and schedule commitments. The test program has been planned to provide high performance, reliability, and safety at an optimum test program cost.

The program is divided into the following major categories.

1. Engineering Test and Evaluation (Component Tests).

2. Motor Verification Tests.

THIS SPACE INTENTIONALLY LEFT BLANK

3. Motor Preliminary Flight Rating Tests (PFRT Tests).

Table 2-1, presented as a foldout at the end of this volume so that it can be used for reference while reading the plan, presents the DDT & E motor and component test programs as defined by Thiokol from contract go-ahead. This schedule provides for the timely submittal of detail procedures for approval, the coordination and phasing of tests, including required customer monitoring, and hardware necessary to meet the major milestones of the test program.

Thiokol implementation of the approved test plan, during the program acquisition phase, will be accomplished as illustrated in Figure 4-1 in block form. This figure defines the flow of data originating from the customer, to the basic test planning, through performance of tests, and the acquisition, handling and reporting of test data and analysis.

4.2 APPLICABLE DOCUMENTS

The following documents of the issue and date specified shall form a part of this test plan to the extent defined herein.

4.2.1 Specifications

NASA

To be determined.

Thiokol Chemical Corporation

To be determined.

4.3 TEST REQUIREMENTS AND OBJECTIVES

This test plan must satisfy the following program requirements.

1. Configuration Item (CI) Detail Specifications, Part I, Section 4, Quality Assurance Provisions.

2. Customer requirements specifically defined in the Statement of Work.

The objective of this test plan is to establish a comprehensive, integrated test program that will demonstrate that the configuration items, components, assemblies, and subsystems used in the SRM Stage and its supporting GSE meet all of the applicable requirements.

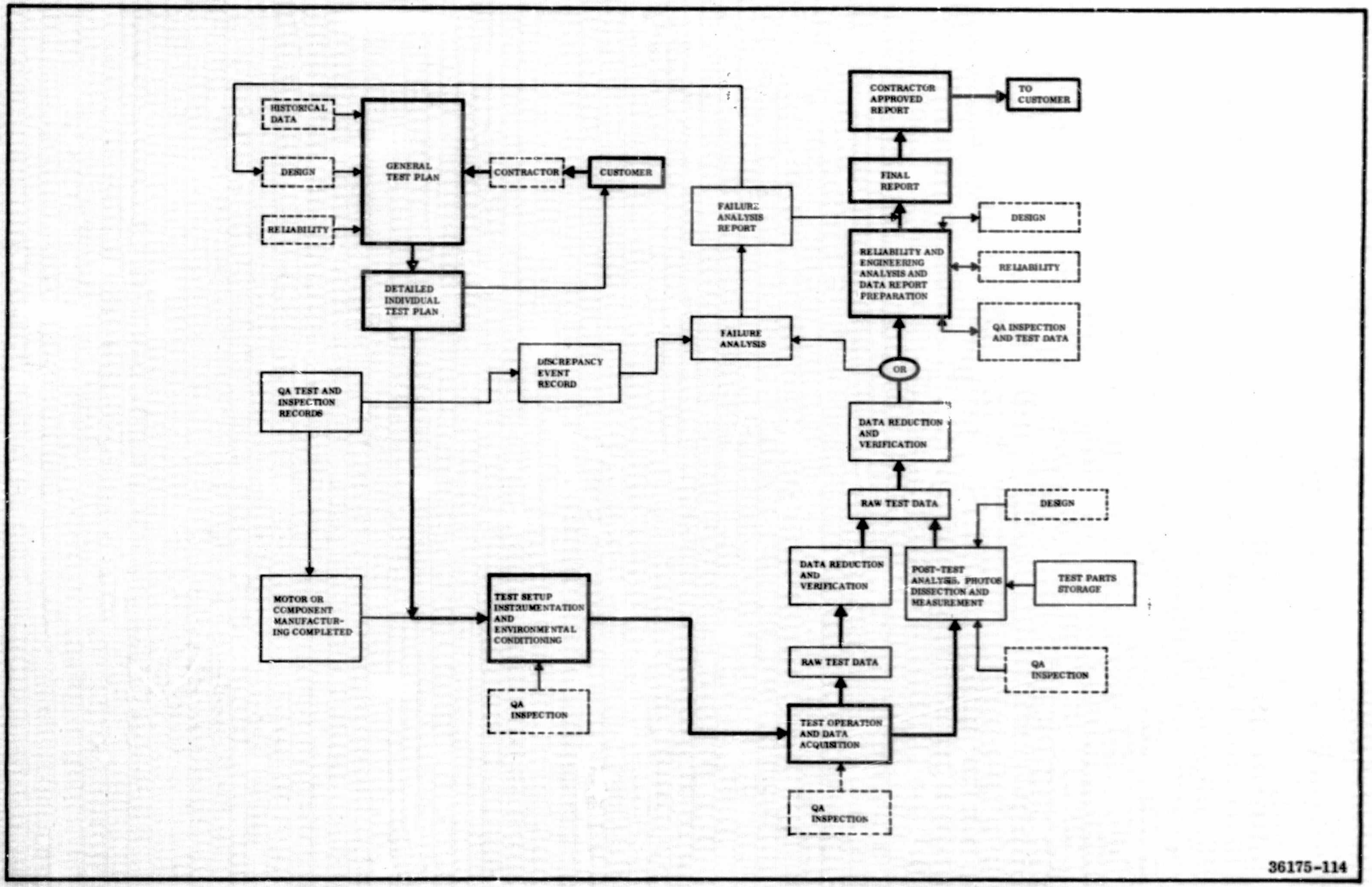


Figure 4-1. DDT & E Test Planning and Data Flow Chart

4.4 ENGINEERING TEST AND EVALUATION

Extensive development testing has been conducted on SRM hardware, beginning in December 1962, with the prime objective of producing a reliable manrated booster stage. Maximum utilization of these data with respect to design and established manufacturing techniques have been incorporated into Thiokol's proposed SRM Stage design. Modifications to the proven design have been allowed only where reliability could be increased or where significant cost savings can be realized at no reduction in reliability or safety. In all areas where design changes have been proposed, the change is supported by historical data gained by Thiokol or established state-of-the-industry techniques.

Engineering test and evaluation will be performed prior to release of production hardware and will include: tradeoff testing; component, subassembly, and module performance evaluation; major breadboard testing; prototype subsystem marriage testing; and detail engineering evaluation of subsystem functional capacities and modification verification. This section describes the specific engineering evaluation testing which will be accomplished.

4.4.1 Propellant and Liner

The proposed Space Shuttle propellant and liner are the TP-H1011 propellant and the UF-2121 liner used in Minuteman Stage I. Over 125 million pounds of TP-H1011 propellant have been produced. The performance and physical properties of TP-H1011 propellant and the UF-2121 liner have been well characterized. No propellant or liner development effort is required to meet Space Shuttle performance or grain application requirements.

The mechanical properties of the propellant and liner, initially and after extended storage, were completely characterized during the Minuteman program. Bond integrity, peel, tensile, and shear are measured and proven characteristics. Stress relaxation modulus and dynamic shear properties were measured to define the viscoelastic characteristics of the propellant. Fatigue endurance properties were measured during the Minuteman transportation and handling program. TP-H1011 propellant physical, mechanical, and ballistic properties tested under aged and accelerated aged conditions have been conducted in the Minuteman Surveillance Program. Hazard classification testing and card gap tests have been completed. The results of these tests show that the proposed propellant and liner system for the Space Shuttle SRM is highly qualified, off-the-shelf, and can be used with no further qualification testing.

A method of production sampling will be used to assure consistent reproducible performance of SRM's provided for the Space Shuttle program. This method consists of making liquid strand burning rate tests, infrared spectrographic analysis, and total solids analyses of each batch of propellant for acceptance prior to being cast into a segment. From the first, middle, and last batch of propellant

in each segment, three 5-in. diameter, center perforate ballistic evaluation motors will be cast and three 1-gal. loaf samples will be cast. The ballistic test motors will be fired to allow prediction of the ballistic performance of the segment and the loaf samples will be tested to verify the physical properties of the propellant in each segment.

4.4.1.1 Test Objectives

During the DDT & E program, propellant testing will be devoted to developing procedures to assure consistent, reproducible performance of the production SRM's and assure the capability to predict SRM performance.

4.4.1.2 Test Description

Thiokol will make two full size mixes of TP-H1011 propellant to evaluate variation of oxidizer grind ratios. Ballistic and physical property data will be determined from nine 5-in. diameter center perforate (CP) motors, 27 uncured strands and nine 1/2 gal. loaf samples from each mix. Normal QC data will be taken.

Thiokol will make two full scale mixes of liner from which physical property data will be determined to show that the liner meets specification requirements.

Each batch of propellant mixed for the verification and PFRT motors will be accepted using liquid strand burning rate tests and total solids analyses prior to pouring into the SRM segment. In addition, three 5-in. CP ballistic test motors and three 1-gal. loaf samples will be taken from each batch of propellant during pouring of the batch. These ballistic test motors will be tested and the data compared with the full scale motor performance data to determine the scaleup factor to be used for ballistic prediction during production. The loai samples will be cut up and tested to assure that the physical properties of the propellant meet specification requirements.

4.4.1.3 Verification Completion

The propellant and liner verification program will be considered complete when the following is accomplished.

1. The test motors manufactured during standardization demonstrate ballistic performance which meets the requirements of the Thiokol design disclosure.

2. Laboratory tests demonstrate that the propellant and liner meet the physical property requirements of the Thiokol design disclosure.

Final qualification will be complete at the completion of the PFRT program.

4.4.2 Rocket Motor Case

The requirements for the Space Shuttle program call for the design and fabrication of highly reliable, low cost, solid rocket motor case segments.

To verify that the design will meet or exceed the design requirements, the case segments will be subject to the tests as shown on Table 4-1.

TABLE 4-1

MOTOR CASE TEST MATRIX

	Hydrotest at Vendor	Hydroburst at TCC
Each Segment Fabricated	All	
Forward, Aft, and One Center Segment Assembled Together		2

Additional Case Testing is described in para 4.4.1.1.

4.4.2.1 Test Objectives

Tests will be conducted to verify the structural integrity of the case hardware under simulated motor operating pressure. Analysis of test data will be conducted to establish predicted burst pressure level and verify case hardware margin of safety.

4.4.2.2 Test Description

After fabrication, each segment of the case will be subjected to a hydrotest to 120% of MEOP at the vendor facility.

For qualification of the case segments, two hydroburst tests will be required. Each test specimen for the hydroburst test will consist of a forward segment and aft segment and one center segment connected together. Each of the two assemblies will be tested to failure. In addition, two forward closures and two aft closures will be subjected to destructive load testing as described in detail in Section 4.4.11 of this test plan.

4.4.2.3 Verification Completion

Case qualification will be considered successfully accomplished when the forward and aft closures with integral skirts have demonstrated capability to withstand flight induced loads, the two hydroburst tests have demonstrated the pressure

integrity of the case design and the verification and PFRT motor testing has been completed.

4.4.3 Internal Insulation

The internal insulation components will be designed to provide protection to the metal case throughout motor action time. The internal insulation will be fabricated from asbestos-silica filled NBR to the Thiokol design requirements. The internal insulation components include the segment wall insulators and propellant stress relief flaps.

4.4.3.1 Test Objectives

The objectives of the insulation component testing is to verify one or more candidate materials for use in the SRM Stage, to verify compatibility among the insulation, case and liner and to bond strengths between the case and insulation and liner and insulation.

4.4.3.2 Test Description

The internal insulation materials and component verification program will be conducted in three phases.

Phase I--Laboratory tests will be conducted in accordance with the Thiokol Material Specifications to determine the physical and chemical properties and insulating characteristics of candidate asbestos-silica filled NBR insulation materials.

Phase II--Four candidate insulation materials will be tested further in accordance with the matrix shown on Table 4-2. These tests will be designed to evaluate the bonding characteristics of the liner-insulation combinations. All testing will be performed in accordance with the master schedule. Only the most promising candidates will be used in Phase III.

Phase III--In this final phase of the program Thiokol will conduct the specific tests and quantities defined in Table 4-3 to demonstrate and verify component fabrication and system bond strength.

1. Component Fabrication Verification

   The insulator manufacturing tooling, procedures, and processes result in insulation material that will properly bond to the D6AC steel case and to the liner.

TABLE 4-2

TESTING MATRIX FOR ALTERNATE SOURCE INSULATION MATERIALS

Candidate Materials	No. 1			No. 2			No. 3			No. 4		
Characterize Bond to Propellant-Liner System												
Liner Thickness (in.)	None	0.045	0.065	None	0.045	0.065	None	0.045	0.065	None	0.045	0.065
Tests and No. of Specimens												
Propellant Adhesion Cup	3	5	3	3	5	3	3	5	3	3	5	3
180 Deg Peel	3	5	3	3	5	3	3	5	3	3	5	3
Characterize Bond to Case												
Tests and No. of Specimens												
Adhesion Disc	--	3	--	--	3	--	--	3	--	--	3	--
180 Deg Peel	--	3	--	--	3	--	--	3	--	--	3	--

TABLE 4-3

TESTING MATRIX TO DEMONSTRATE INSULATION SYSTEM FABRICATION CAPABILITY

Insulation Material	Candidate X			Candidate Y		
Liner Thickness (in.)	None	0.045	0.065	None	0.045	0.065
Propellant	X	X	X	X	X	X
Test and No. Specimens						
Double Plate Tensile	3	5	3	3	5	3
Double Plate Shear	3	5	3	3	5	3
90 Deg Peel	3	5	3	3	5	3

2. System Bond Strength Verification

Thiokol's capability to produce and process insulation meeting all requirements of the individual materials specifications, and the composite system (case, insulation, liner, propellant) bond strength requirements in the SRM specification will be demonstrated and verified by the tests shown in Table 4-3.

To assure that the data from the sample testing will be representative of the full scale motors, liner and propellant used for these samples will be taken from full scale mixes prepared during the initial liner and propellant standardizations.

These composite test specimens will be prepared from materials which have been subjected to the same environment they will experience during normal motor processing. The insulation material will be cured in the same manner and for the same time-temperature history as the motor insulation would experience. After removal of the molding tooling, the insulation specimen will be prepared for liner application using the same process as specified for the motor. Liner will be applied and cured for the prescribed time-temperature history. Propellant will be cast and cured using the motor time-temperature specifications.

Composite test specimen will be prepared in accordance with NASA approved Thiokol specifications.

The candidate alternate source insulation materials successfully passing all of the tests defined will be utilized to fabricate a minimum of two of each configuration of insulators for use in the verification motor program. Post-test examination of each insulator used in the verification motor program will be accomplished to discern any differences among the candidate materials. Each candidate material will be examined in detail to determine insulation characteristics in actual motor testing. Candidates considered adequate for motor use will be further tested in the PFRT motor test program. All candidate materials which successfully pass verification and PFRT motor testing will be considered as acceptable alternate materials for use in the production program. All insulator fabrication tooling, processes and procedures for use in the production program will be developed and demonstrated during the verification and PFRT motor program.

4.4.3.3 Verification Completion

The internal insulation qualification will be considered complete when the laboratory testing and inspection of insulators and materials demonstrate that they meet specification requirements. Final qualification of the system will be complete at the end of the PFRT motor testing program.

4.4.4 Nozzle and Flexible Bearing

The nozzle identified herein is that equipment interfacing with the loaded segment of the SRM and the actuation system components. It is an axis movable nozzle capable of ± 5 degree deflection for thrust vector control. The gimbaling mechanism is a flexible seal assembly and is considered a part of the nozzle.

4.4.4.1 Test Objectives

The test objectives are to verify nozzle and flexible seal performance, function, and integrity.

4.4.4.2 Test Description

4.4.4.2.1 Nozzle Components and Materials

Samples of raw materials and samples from all finished components will be tested to verify compliance to design drawings and specifications. Testing will include determination of physical properties, chemical compositions, and part quality.

The finished ablative and insulative plastic materials will be tested for density, tensile strength, compressive strength, resin content, and volatiles for conformance to the specification. All components will be X-rayed for detection of internal defects. From each lot of plastic raw materials, three specimens will be tested for verification of compliance to the raw materials specifications. (See Table 4-4). Two nozzle structural housings will be hydroburst tested to verify design margin of safety.

4.4.4.2.2 Flexible Seal Assembly

Two prototype flexible seal assemblies will be fabricated and tested as follows: (See Table 4-5).

1. Bench tested in a fixture by vectoring through a duty cycle which includes maximum design and anticipated flight deflections and slew rates while under 120% of MEOP pressure loading. Seal axial deflections, pivot point location and actuation torques will be determined.

2. Leakage tested while in tension loading.

3. Twang tested - snap back and oscillatory damping when released suddenly and unrestrained from a maximum deflected position.

TABLE 4-4

NOZZLE DEVELOPMENT TEST MATRIX

	Hydro-burst	Resin Content	Volatile Content	Resin Flow	Density	Tensile Strength	Comp Strength	X-Ray	Static Test
Ablative and insulative Raw Materials (3 samples each lot)	--	X	X	X	--	--	--	--	--
Molded Flat Slabs from Raw Materials (3 samples each lot)	--	X	X	--	X	X	X	--	--
Cured Plastic Component (3 each comp)	--	X	X	--	X	X	X	All	--
Steel Housing	2	--	--	--	--	--	--	--	--
Nozzle Assembly (Verification Motors)	--	-	--	--	--	--	-	5	5
Nozzle Assembly (PFRT Motors)	--	--	-	--	--	--	--	5	5

TABLE 4-5

FLEXIBLE BEARING DEVELOPMENT TEST MATRIX

	Bench Test	Leak Test	Twang Test	Destruct	Static Test	Hydroburst
Prototype-1	1	1	1	1	-	-
Prototype-2	1	1	1	1	-	-
Verification	5	5	5	-	5	-
Steel Housing	-	-	-	-	-	2
PFRT and Production	X	X	X	-	-	-

4. Destruct-vectored at increasingly higher pressure loads until failure.

5. Normal quality control inspection functions will be conducted.

All subsequent seal assemblies will be tested in the same manner except for the destruct test.

4.4.4.2.3 Steel Housing Assembly

Two steel housing assemblies will be fabricated and subjected to hydroburst tests to verify the integrity of the design.

4.4.4.3 Complete Nozzle Assemblies

One complete nozzle assembly will be subjected to temperature, humidity, and missile vibration environments. Before and at the completion of environmental testing, the nozzle will be inspected to determine its integrity. The tests will be performed in accordance with the master schedule. This nozzle then will be installed and static tested on verification motor number two. Nine new nozzle assemblies, fabricated using tooling, processes and procedures intended for production, will be delivered and static tested on the development and PFRT motor static tests.

4.4.4.4 Verification Completion

The nozzle qualification will be considered complete when the tests outlined in the preceding subsections have been conducted, and the materials and nozzle shown to meet specification requirements. Final qualification of the nozzle will be completed at the completion of PFRT Motor Testing Program.

4.4.5 Nozzle Actuation System

The nozzle actuation system for the SRM Stage will be tested to verify that the system performance meets or exceeds the design requirements. The inhouse breadboard and flight system verification tests shall precede component qualification tests conducted by the vendor.

The nozzle actuation system consists of the HPU, tandem actuators, hydraulic components, control unit, monofuel system, and the associated valving. The component and system tests include cold performance tests, proof tests, temperature tests, vibration tests, shock tests, burst tests and hot performance tests as shown on Table 4-6.

4.4.5.1 Test Objectives

To demonstrate that the design selected and the component parts will perform to the design requirements in the presence of the environmental conditions imposed by the mission.

4.4.5.2 Test Description

Component prototype testing will be performed at the vendors. These tests are to verify the design changes to existing hardware. Development bench testing on major new components, such as the tandem actuator using majority voting servos will require extensive vendor bench testing. Less critical actuation system components will not require breadboard demonstration at the component level. However, system verification type bench tests using prototype hardware will be performed at Thiokol preceding the final flight hardware production. Following these prototype tests, the vendors will fabricate and check out the flight hardware components. Thiokol will perform Flight System Verification tests on the entire nozzle actuation system preceding the vendor component qualifications.

The qualification of the nozzle actuation system is a three-fold test. The vendors will subject four flight hardware components to full-up qualification testing (proof, temperature cycling, vibration, shock, and burst). This will be followed by entire environmental system tests at Thiokol (proof, temperature cycling, vibration, shock, burst and hot run). Final qualification efforts will be to functionally test the full-up Flight System on 10 SRM's during motor static firing.

4.4.5.3 Verification Completion

The thrust vector control system qualification will be considered completed upon successful completion of the component and system testing described above. Final qualification will be completed upon successful completion of the motor verification and PFRT testing using the thrust vector control system on each motor static firing.

TABLE 4-6

NOZZLE ACTUATION SYSTEM TEST MATRIX

Test Description	Test Location	Cold Perf	Proof	Temp	Vibra	Shock	Burst	Hot Perf	System Oper
Prototype - Component Checkout (1 set)	Vendor	X	X	--	--	--	X	X	--
Prototype - System (1 set)	TCC Eng Lab	X	X	--	--	--	X	X	X
Flight Component Checkout (1 set)	Vendor	X	X	--	--	--	--	X	X
Flight System Verification (1 set)	TCC Eng Lab	X	X	--	--	--	X	X	X
Flight Component (4 Sets) Qualification	Vendor	--	X	X	X	X	X	X	--
Flight System (2 sets) Environmental	TCC Eng Lab TCC Test Area	--	--	X	X	X	X	X	X

4.4.6 Ignition System

The ignition system for the SRM for the Space Shuttle system shall consist of a single train ignition consisting of the following component items.

1. Safety and Arming Device (S & A)
2. Pyrotechnic Booster Charge
3. Initiating Pyrogen Igniter
4. Main Pyrogen Igniter

The requirements of the Space Shuttle program call for highly reliable ignition of the SRM. To verify that the components meet or exceed the design requirements, the ignition components will be subjected to the tests shown in Tables 4-7 and 4-8.

4.4.6.1 Test Objective

Tests will be conducted to develop an ignition system and to verify that the ignition system will comply with the design requirements for the SRM ignition.

4.4.6.2 Test Description

The development of the ignition system will include testing of the igniter components by adhesion tests, hydroproof and hydroburst tests, vendor qualification of the S & A devices, and static firings of the complete system.

The adhesion tests will consist of testing 40 specimens each for internal insulation to chamber bond, external insulation to chamber bond, propellant to liner to internal insulation bond, and nozzle insert to chamber bond.

The hydroproof and hydroburst tests will include three specimens each of pyrotechnic chamber, initiating Pyrogen chamber, and main Pyrogen chamber.

Six of the igniters will be static fired to check ignition from S & A to pyrotechnic pellets to initiating Pyrogen igniter, and ballistic performance of the initiating Pyrogen igniter. Six complete ignition systems will be static fired to check the ignition and ballistic performance of the main Pyrogen igniter and to test structural integrity and survivability of the chamber, nozzle insert, and internal insulation. Two systems will be temperature conditioned to 65°F, two at 80°F and two at 95°F prior to static testing.

TABLE 4-7

IGNITION SYSTEM DEVELOPMENT TEST MATRIX

	Number of Specimens			Environmental Tests			
Development	Adhesion Tests	Hydro-proof	Hydro-burst	Transport Vibration	Handling Shock	Temp & Humidity	Static Firing
Internal Insulation to Chamber	40	--	--	--	--	--	--
External Insulation to Chamber	40	--	--	--	--	--	--
Propellant to Liner to Internal Insulation	40	--	--	--	--	--	--
Nozzle Insert to Chamber	40	--	--	--	--	--	--
Pyrotechnic Chamber	--	All	3	--	--	--	--
Initiating Pyrogen Chamber	--	All	3	--	--	--	--
Main Pyrogen Chamber	--	All	3	--	--	--	--
Igniter Assy (less main Pyrogen Igniter)	--	--	--	--	--	--	6
Igniter Assy (Complete)	--	--	--	--	--	--	6
Qualification							
Igniter Assy (Complete)	--	--	--	3	3	3	3

TABLE 4-8

IGNITION SYSTEM
SAFE AND ARM DEVICE QUALIFICATION TEST MATRIX

	Visual Inspection	Trans Vibration		Acceleration (3 axis)	Vibration (3 axis)	Life Cycles	ARM Power to Stalled Device	Temp & Humidity	Temp Altitude	Performance Testing				Post-Test Disassemble
		Unpackaged	Packaged							Both Squibs	Squib No. 1	Squib No. 2	Squib 1 & 2 Individually	
Engineering Evaluation (6 units)	3	6	--	6	6	6	6	--	--	--	--	--	3	--
Qualification Testing (33 units)	33 (1)	33 (1)	33 (1)	33 (2)	33 (1) (2)	1 (1)	1 (1) (2)	33	33 (1)	4	3	3	20	33 (3)

NOTES: (1) At least one electrical checkout required at this point

(2) Checkout to include fire pulse circuit check

(3) Three devices disassembled after environmental testing
Thirty devices disassembled after functional tests

Qualification tests of the ignition system will consist of static firing three ignition systems after being subjected to the environmental tests of transportation vibration, handling shock, temperature, and humidity.

Qualification of a Safety and Arming device to be used on the ignition system will be required. The six unit engineering evaluation and 33 unit qualification programs will be performed at the vendor facilities in accordance with Table 4-8.

4.4.6.3 Verification Completion

The ignition system qualification will be considered complete when nine complete igniter assemblies have been static tested and have met the performance requirements defined in the CEI Specification. All ignition systems for the motor verification and PFRT Programs will be received, inspected, and fabricated as applicable using the design disclosure, tooling processes, and procedures intended for use during the production program. Final qualification of the ignition system will be complete at the end of the PFRT Motor Test Program.

4.4.7 Thrust Termination System

The SRM thrust termination (T-T) system will consist of the following component items:

1. End Primer
2. Transfer Leads
3. End Fitting Material
4. Manifold
5. Shaped Charge
6. Safe and Arm Device (S&A)

The requirements of the program call for a highly reliable thrust termination system. The T-T components and complete system will be subjected to the tests on Tables 4-9 and 4-10. The T-T system will use a circular shape charge with side ignition.

4.4.7.1 Test Objectives

Tests will be conducted to verify conformance to the specification for thrust termination systems of the SRM Stage.

4.4.7.2 Test Description

The design of the thrust termination system will include testing of the end primer, the end fitting material, and the manifold. The end primer will be subjected to tests of initiation by detonator through a barrier, butt to butt transfer, and side initiation.

Selection of primer explosive transfer lead material will be made by the vendor to meet the design requirements. The selection of internal transfer leads for the manifold, manifold material, and manifold design for safety will be made by the vendor. The manifold will be tested for installation of looped lead, holding end tolerances, for normal propagation, and for abnormal propagation. Also the shaped charge will be tested for ignition from various locations and angles.

Development testing for angle of penetration, stand-off, charge size and penetration, and pressurized vs unpressurized vessels will be conducted using 33 complete breadboard assemblies on steel case sections with internal insulation bonded in place.

TABLE 4-9

THRUST TERMINATION SYSTEM TEST MATRIX

Tests	End Primer	Manifold	Shape Charge	Complete Assembly
Initiation by Detonation Through a Barrier	30	--	--	--
Butt to Butt Transfer	15	--	--	--
Side Initiation	15	--	--	--
Installation of Looped Lead	--	15	--	--
Normal Propagation	--	10	--	--
Abnormal Propagation	--	5	--	--
Angle of Penetration	--	--	8	--
Stand-Off	--	--	4	--
Charge Size	--	--	15	--
Penetration Pressurized	--	--	2	--
Penetration Unpressurized	--	--	2	--
Initiation Tests End Primer to Shape Charge	45	--	45	--
Verification Tests (Prefiring Environmental Tests)	--	--	--	--
Transportation Vibration	--	--	--	6
Flight Vibration	--	--	--	6
Temperature and Humidity	--	--	--	6
Acoustic	--	--	--	6
Acceleration	--	--	--	6
Static Test DM-3	--	--	--	1

TABLE 4-10

THRUST TERMINATION SYSTEM
SAFE AND ARM DEVICE QUALIFICATION TEST MATRIX

	Visual Inspection	Trans. Vibration		Acceleration (3 Axis)	Vibration (3 Axis)	Life Cycles	ARM Power to Stalled Device	Temp & Humidity	Temp Altitude	Performance Testing				Post Test Disassemble
		Unpackaged	Packaged							Both Squibs	Squib No. 1	Squib No. 2	Squib 1 & 2 Individually	
Engineering Evaluation (6 units)	3	6	--	6	6	6	6	--	--	--	--	--	3	--
Qualification Testing (33 units)	33 (1)	33 (1)	33 (1)	33 (2)	33 (1) (2)	1 (1)	1 (1) (2)	33	33 (1)	4	3	3	20	33 (3)

NOTES:

(1) At least one electrical checkout required at this point

(2) Checkout to include fire pulse circuit check

(3) Three devices disassembled after environmental testing
Thirty devices disassembled after functional tests

Verification will consist of 30 complete assemblies mounted on steel case sections with internal insulation bonded in place. The entire assembly will be subjected to environmental tests of transportation vibration, flight vibration, temperature and humidity cycling, acoustic noise, and acceleration before the ignition test.

Qualification of the Safe and Arm device to be used in the thrust termination system will be required. The six unit engineering evaluation and 33 unit qualification program will be performed at the vendor facilities in accordance with Table 4-10.

4.4.7.3 Verification Completion

Qualification of the thrust termination system will be considered completed when the 30 systems subjected to environmental testing have been successfully static tested. Final qualification of the complete thrust termination system will be accomplished by firing the thrust termination system on DM-3 during motor action time.

4.4.8 Malfunction Detection System

The Malfunction Detection System (MDS) will be classified into the following categories:

1. Malfunction Detector with "enable" and "disable" circuit, one for each SRM required.

2. Operational Pressure Transducer (OPT), three required for each SRM, mounted on the headend.

3. Indicator, one required for the SRM Stage, located in the orbiter.

4. Airborne Power, supplied by the flight power.

The design of the MDS will include solid state electronic circuits for the detection and display of differences in chamber pressure between the two SRM's. If a pressure difference between the chambers of the two SRM's occur, a display in the orbiter will immediately indicate that this difference exists. If pressure in one SRM is lost, the indicator will identify the SRM at fault. The design to accomplish this will use redundant pressure measurements from each SRM.

Three pressure transducers on the headend of each SRM will measure the chamber pressure. Signals from these transducers are fed to a solid state electronic comparator circuit, where the signals from the two transducers on each SRM that are nearest the same level are selected to provide a chamber pressure signal to the orbiter. The chamber pressure signals from the two SRM's are fed to differential comparator circuit, which will detect and indicate to the pilot the deviation of chamber pressures between SRM's.

The response time of the MDS will be limited by the frequency response of the indicator. The order of magnitude will be in the millisecond range response time.

Design and qualification specifications will require the MDS to perform its normal function after being subjected to transportation and handling, vibration, shock, and temperature environments. Also, the MDS must operate within the specified accuracy during the flight environment, acceleration, vibration and temperature altitude. To verify this capability, the MDS will be subjected to the testing shown in Table 4-11.

TABLE 4-11

MALFUNCTION DETECTION SYSTEM TEST MATRIX

	Environmental												Performance											
	Complex Vibration	Acceleration	Temperature-Altitude	Humidity	Storage Life	Hermetic Seal	Frequency Response	Output Impedance	Power Transients	EMI	Fungus, Salt Spray, Sand and Dust	Reliability Tests[1]	Output Voltage	Noise	Nonlinearity	Hysteresis	Isolation	Calibration	Overpressure	Thermal Zero Shift	Thermal Sensitivity Shift	Operating Current	Operating Voltage	Used on Static Tests
Operational Pressure Transducer (9 units)	4	4	4	4	4	4	4	4	4	1	1	5	9	9	9	9	9	9	9	9	9	9	9	
Malfunction Detector and Indicator Circuits (9 units)	4	4	4	4	4	4	4	4	4	1	1	5	9	9	9	9	9	9	9	9	9	9	9	
MDS System (7 systems)[2]																								10

NOTE: (1) Reliability tests include repeated operational cycling, simulated flight environment, and safety reliability.

(2) The first three systems will be recycled for later tests.

The power distribution box will contain provisions to electrically "enable" or "disable" the MDS circuitry by command signal received from the orbiter.

4.4.8.1 Test Objectives

The test objectives are to demonstrate that the design selected for the MDS will meet or exceed the design requirement in the presence of the imposed mission environment.

4.4.8.2 Test Description

The components of the malfunction detection system which include the operational pressure transducers and the malfunction detection circuit with the accompanying "enable" and "disable" circuit, will be subjected to the environmental and performance tests for qualification at the vendor facilities. The Test Matrix for the environmental and performance tests is shown on Table 4-11. Also included on the table are the combined system tests which will be the ten static firings of the SRM, DM-1 through DM-5, and PFRT-1 through PFRT-5, at the Thiokol Test Facilities. Seven systems will be tested with three systems being recycled for a total of ten tests. Individual test plans for component qualification will be submitted for NASA approval prior to the qualification program. To insure compliance to the test specification Thiokol will monitor all qualification testing. Customer monitor of the testing will also be invited.

4.4.8.3 Verification Completion

The MDS will be qualified for the Space Shuttle program upon completion of the component testing described above and upon completion of the verification and PFRT motor tests.

4.4.9 Instrumentation System

The SRM Instrumentation system consists of an instrumentation enclosure containing the signal conditioners and external power switching circuits, an instrumentation battery, and those end instruments required to supply subsystem events to the instrumentation enclosure. The signal conditioners within the instrumentation enclosure are required to condition the output from the end instrument and provide these signals to a multiplexer in the Space Shuttle vehicle. The external power switching circuits will switch the instrumentation system from ground power that will be used for preflight checkout to the airborne instrumentation battery which will be used during flight. A list of the events to be measured during flight is presented in Table 4-12. The instrument enclosures will be tested in accordance with Table 4-13. The flight batteries will be a previously qualified battery system which does not require qualification.

4.4.9.1 Test Objectives

The test objectives are as follows:

1. Demonstrate that the instrumentation enclosure design selected and the components chosen will perform in the presence of mission environments.

2. Demonstrate the structural adequacy of the instrumentation enclosure design to prevent out-of-tolerance performance parameters due to environmental influence.

4.4.9.2 Test Description

Four instrumentation enclosures will be subjected to the environments of Table 4-13 and will, without degradation, perform functionally as noted below:

1. Two power supplies, a battery for flight power and a bench level 28 vdc supply to simulate ground power prior to switchover, will power these units.

2. The ability of the instrumentation enclosure to accept power from on-board battery and ground power through the remotely operated self-contained power transfer switch will be demonstrated.

TABLE 4-12

RECOMMENDED FLIGHT INSTRUMENTATION LIST

2	Pressure Measurements
2	Radiometer Measurements
2	Calorimeter Measurements
15	Temperature Measurements
15	Acceleration Measurements
1	Thrust Termination Measurement
1	ISDS Measurement
1	Destruct Command Measurement
1	Staging Command Measurement
2	Nitrogen Squib Valve Monitors
2	Nitrogen Regulation Pressures
2	Monofuel Pressures
2	Decomposition Chamber Pressures
2	HPU - Starter Grain No. 1
2	HPU - Starter Grain No. 2
2	Turbine Speed Magnetic Pickups
2	28 VDC Power Bus A
2	28 VDC Power Bus B
4	EDV (Pump) Monitors
2	Lube Oil Temperatures
2	Hydraulic System Pressures
2	Hydraulic System Returns
4	Differential Pressures
8	TVC Commands
8	TVC Feedbacks
4	Failure Indicator Switches
8	Arm-Disarm Signals
4	Battery Initiator Monitors
4	Control Box Monitors
108	Total Channels

TABLE 4-13

INSTRUMENTATION ENCLOSURE TEST MATRIX

Environment	Level (Description)	Breadboard	Operating	Nonoperating
Temperature	25° to 160°F	X	X	
EMI	With the unit in the operating condition, the following tests will be conducted to show compliance with the limits shown in the specification (1) radiated emission (2) conducted emission (3) radiated susceptibility (4) conducted susceptibility	X	X	
Temperature Altitude	25° to 160°F 0 to 150,000 ft			X
Vibration	Random Flat 800 to 1200 cps at 1.0 g^2/cps Roll-off below 800 cps at 3 db/octave Roll-off above 1200 cps at 6 db/octave Overall = 35.7 grms Test Duration: 315 sec/axis		X	
Shock	100 g terminal Sawtooth 10.5 ms Rise time 0.5 ms max Decay		X	

3. Laboratory supplied instrument signals will be sent to the instrumentation enclosure, and the output will be monitored for proper type, bilevel or analog, quality and level of signal. The types of signals that must be simulated are shown in Table TBD.

4. Laboratory noise signals will be induced and the output monitored to demonstrate the special filter module's capability to clean up noisy signals.

Anomalies that may occur during these tests will be evaluated for cause and effect. The results will be analyzed for corrective action.

4.4.9.3 Verification Completion

The instrumentation system verification will be considered complete when the flight batteries have been documented to be flightworthy units and the instrumentation enclosure has completed the tests defined above. Final qualification will be completed when the instrumentation system has been successfully tested on the verification and PFRT motor static tests.

4.4.10 Cable Assembly

The cable assemblies involved in the design verification will include all cables used for carrying control signals, power, and instrumentation. The tests on the cables will subject the cables to the selected environments as shown on Table 4-14 to verify the design as being capable of satisfying performance requirements in the SRM Stage application.

4.4.10.1 Test Objectives

The objective of these tests is to demonstrate that the materials and fabrication techniques chosen for each cable design are adequate for the operational function it must perform under applicable environmental conditions.

4.4.10.2 Test Description

Two samples of each type of cable assembly to be used in the SRM Stage will be fabricated and completely checked for continuity and insulation resistance before starting these tests. These data will be used for the baseline and will be taken by means of automatic circuit checkout equipment.

TABLE 4-14

CABLE ENVIRONMENTAL TESTS

Environment	Description	No. Cables
Thermal Shock	Subject assembly to 5 continuous cycles of temperature change between 25° and 160°F. Hold each extreme for one hour. Maximum time between temperature change is 5 minutes.	2 of each design
EMI	Specific EMI requirements will be established with vendors for their particular component. Compliance will be assured by technical surveillance and QC inspection.	2 of each design
Cold Bend	Maintain assembly at 25°F for 12 hours. Raise the temperature to 50°F for two hours. Examine cable and bend about a mandrel. The bend radius is minimum of TBD.	2 of each design

Table 4-14 describes the environments to which each cable will be subjected. The operating functions including continuity and insulation resistance checks will be performed before and after each of the environmental tests. In addition to this check, visual inspection shall be made for deterioration of materials or damage to mechanical joints.

4.4.10.3 Verification Completion

The cable qualification will be complete when each of the cable types has completed the testing described above and when the cables have been tested on the verification and PFRT motor tests.

4.4.11 Interstage Structures

The requirements for the Space Shuttle Program call for the design of highly reliable interstage structures capable of carrying the thrust of and providing aerodynamic bearings for the SRM. The interstage structure consists of the following components.

1. Nose Cone
2. Aft Skirt Extension
3. Main Struts
4. End Fixtures
5. Sway Bars
6. Braces

To verify that the components meet or exceed the design requirements, the SRM interstage structures will be subjected to the tests as shown on Table 4-15.

4.4.11.1 Test Objectives

The test objective is to verify the structural integrity of the SRM interstage structures under load conditions.

4.4.11.2 Test Description

The nose cone qualification test will consist of two nose cones being subjected to pressure tests. Each of the nose cones will be subjected to pressures that will simulate 1.4 times the maximum expected load. Each nose cone then will be subjected to an overpressure test to failure.

The qualification test for the attach hardware will consist of a load and stiffness test to failure on ten each of the main struts, end fixtures, sway bars, and braces.

In addition, two combine tests of case segments and interstage structures assembled together will be conducted. Two load and stiffness tests will be conducted on the forward segment with the forward interstage structure and nose cone attached. Two similar tests will be conducted on the aft segment with the aft skirt and aft interstage structure attached. These load and stiffness tests will be carried to limit load conditions to determine deformation, stresses and strains and then will be carried to structural failure to determine ultimate load capabilities.

TABLE 4-15

INTERSTAGE STRUCTURE TEST MATRIX

Specimen	Load and Stiffness to Failure	Overpressure to Failure
Nose Cone		2
Aft Skirt	2	
Main Struts	10	
End Fixtures	10	
Sway Bars	10	
Braces	10	
Combine Tests of Case Segments and Structures		
Forward Assembly	2	
Forward Segment		
Nose Cone		
Interstage Structures		
Aft Assembly	2	
Aft Segment		
Aft Skirt		
Interstage Structures		

4.4.11.3 Verification Completion

The interstage structures qualification will be complete upon the successful completion of the testing described above.

4.4.12 Recovery System

Each SRM will have its own recovery system which will be an aerodynamic decelerator device. This system will be used to recover the expended SRM case by use of parachute decelerator devices.

The recovery system will be designed to include the following component parts:

1. Pilot Parachute
2. Drogue Parachute
3. Main Parachute
4. Mortars for Deployment
5. Pyrotechnic Release Device
6. Power Supply
7. Beacon System
8. Entry Spin System

The qualification tests of the individual components and the recovery system assembled will be accomplished at the vendor facilities. The recovery system itself will be designed to be recoverable.

4.4.12.1 Test Objectives

Tests will be conducted on the components and on the aerodynamic decelerator system to verify that the recovery system will meet the requirements for recovery of the expended SRM case on the Space Shuttle Program.

4.4.12.2 Test Description

4.4.12.2.1 Recovery System Developmental Testing

Along with the analytical design of the booster recovery system, attendant model testing will be required. Following is a description of the test programs to be conducted in the development program.

Reentry Tumbling--Tests will be conducted to evaluate the reentry tumbling dynamics. These tests will evaluate and substantiate theoretical calculations of dominant stable attitudes or spin modes. In addition, the effect of different sizes and configurations of spin fins will be determined. Tests of a scale gimbal mounted model in the supersonic wind tunnel will be performed.

Runs will be made at Mach numbers in the range of 6 thru 1. In addition, sounding rocket test of scale models will be performed to verify the altitude pressure and Mach number regime. Telemetry data of altitude rates of these sounding rocket tests will be recorded. Altitude history from ground radar data and/or cinetheodolity will also be recorded.

Despin Drogue Deployment--To assure that the drogue chute will despin the rocket case and to evaluate the dynamic loads on that chute, tests in a transonic wind tunnel facility will be performed. A scale gimbal mounted model with a scale drogue parachute will be tested in a wind tunnel at Mach numbers of 1.2 to 0.8.

After the wind tunnel tests have been conducted and the drogue system hardware designed, scale drop tests will be performed. A one-third size drogue chute and suspended weight model will be dropped from a B-52 aircraft. These tests will require tensiometers on the drogue bridle load points and accelerometers on the suspended weight body. In addition, a cinethodolite will be required.

Main Parachute--Because of the size of the main parachute system, scaling of wind tunnel size models is thought to be undesirable. Drop testing of 1/3 scale models including the clusters of six parachutes will be performed. These tests will evaluate the cluster aerodynamic deployment, dynamic loads, and descent rates. In addition, a full scale test of a single parachute with a 1/6 suspension weight will be performed. This test will be performed for parachute structural integrity validation. Static pull tests of the parachute seam and joint stitches, pocket band construction, and reefing joint ties will be performed.

Mortars for Deployment--Subsystem testing of the pilot chute mortars will be performed to evaluate breach pressures, power unit throat erosion rates, and muzzle exit velocities. These tests will be conducted on the ground at a subcontractor test facility.

Pilot Parachute--The design testing of the pilot chute will be conducted on a test vehicle, either a sled or a high speed aircraft.

4.4.12.2.2 Recovery System Qualification Testing

Qualification testing will involve repeating many of the developmental tests, in some cases to destruction. All system components will be subjected to temperature, humidity, vibration and environmental testing.

The main and drogue parachutes will be tested in B-52 drop tests with increasing loads. The greater parachute loads will be caused by increased deployment velocities and suspended weights. These tests should establish the variation in decelerator performance and design system safety margin.

The structural integrity of the entry system spin fin will be tested by static aircraft type multiply point loads procedure.

The mortars, pyrotechnic release devices, power supply and beacon system will be ground tested for a matrix of environment conditions.

4.4.12.3 Qualification Completion

The recovery system qualification will be considered complete upon successful completion of the model and full size component testing and upon successful recovery of an SRM Stage during the Space Shuttle Vehicle Flight Test Program.

4.5 DESIGN VERIFICATION AND PRELIMINARY FLIGHT RATING TESTS

The design verification and Preliminary Flight Rating (PFRT) test program for the Solid Rocket Motor (SRM) has been designed to demonstrate that the SRM meets Space Shuttle operational system performance requirements. This will be accomplished by the static firing of five verification motors and five (PFRT) motors at the Thiokol test facilities. The test arrangement to be used is shown pictorially in Figure 4-2, and the SRM test matrix is shown in Table 2-1.

Solid rocket motor production hardware components to be tested will be inspected and accepted in accordance with the applicable NASA approved specifications. Prior to test, the manufacturing logbook, inspection records, quality control records and other documents required to evaluate the SRM and associated equipment will be made available for customer review. In addition, all test apparatus will be available for inspection and review by the customer.

A detailed test plan will be prepared and submitted to the customer 30 days prior to each SRM static test. This test plan will identify primary and secondary objectives, instrumentation requirements, test firing bay, motor configuration, test conditions, applicable test procedures, data reduction and reporting requirements.

Design verification and PFRT SRM test firings will be conducted in accordance with the SRM test matrix, Table 2-1.

4.5.1 SRM Test Purpose and Success Criteria

The design verification and PFRT SRM test program objectives are to: (1) demonstrate compliance with performance requirements under simulated operational environmental conditions; (2) confirm design functionality; and (3) verify specification performance and acceptance requirements. Successful completion of these objectives will produce maximum confidence of configuration items reliability for operational use.

Preliminary flight rating tests (PFRT) are formal tests oriented to achieve acceptance of performance and design characteristics of the SRM prior to integrated testing with the Space Shuttle vehicle.

The SRM Stage success criteria will be established and will provide a basis for evaluating the performance of the SRM. The mission success criteria will be based on selected parameters which provide the best overall measure of the motor performance, while avoiding overlapping measurements.

4.5.2 Static Test Primary Objectives and Success Criteria

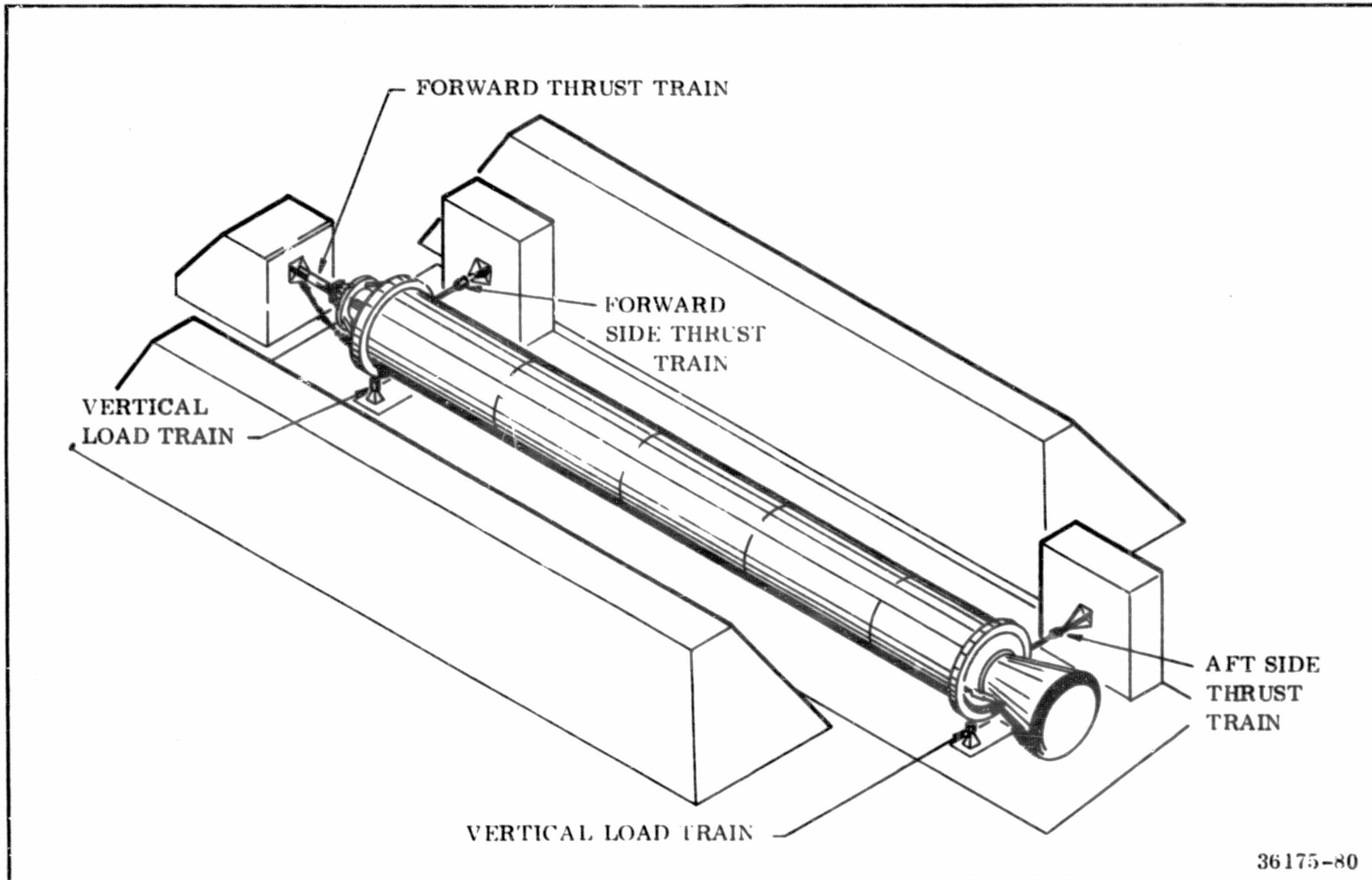


Figure 4-2. Test Bay Arrangement

4.5.2.1 Verification of Motor Ballistic Performance Parameters Under Various Environmental Temperature Conditions

Successful accomplishment of this test objective shall be demonstrated by comparing the following measured ballistic parameters with SRM Stage mission success requirements.

1. Motor chamber pressure during ignition.
2. Motor instantaneous thrust vs time.
3. Motor web action time.
4. Motor web action time total impulse.

4.5.2.2 Verification of Structural Integrity of the SRM Propellant Grain

Successful accomplishment of this test objective shall be demonstrated by:

1. Analysis of ballistic performance test data to establish compliance to 3 sigma specification requirements under test firing conditions.
2. Satisfactory performance of a forward closure, center segment and aft closure during motor static firing after exposure to transportation and handling shock and acceleration simulation testing.
3. Satisfactory performance of a forward closure, center segment and aft closure during motor static firing after exposure to extreme temperature cycling testing.

4.5.2.3 Verification of Motor Case Performance

Motor case performance will be verified primarily by post-test analysis of case hardware. Successful demonstration of the case hardware will be established by:

1. Satisfactory performance of the case as a pressure vessel.
2. No evidence of case deformation during motor operation.

4.5.2.4 Verification of Internal Insulation Performance

Internal insulation will be verified by post-test analysis of fired case and closure segments and by analysis of motor case temperature profiles during static test. Successful demonstration of this test objective will be established by:

1. Satisfactory levels of remaining virgin insulation material.
2. Acceptable erosion profiles of flow surfaces.
3. Evidence of satisfactory propellant to liner bond integrity.
4. Satisfactory motor case temperature profiles.

4.5.2.5 Verification of Nozzle Performance

Successful demonstration of this test objective will be established by:

1. Acceptable erosion profiles of nozzle flow surfaces.
2. No detrimental heat and char penetration in the ablative liner materials.
3. Satisfactory conditions at bonded composite interfaces between ablative liners and backup materials.
4. Satisfactory internal conditions of the plastic components relative to cracking, delamination and structural integrity.

4.5.2.6 Verification of Thrust Vector Control System Performance

The thrust vector control system will be verified by comparison of static test performance with specification requirements. Successful demonstration will be established by:

1. Nozzle actuation in accordance with the commanded static test duty cycle.
2. Gas generator and hydraulic pressure levels, turbine speed and operating temperature.
3. Measured thrust vector side forces and axial thrust.
4. Actuator operation and feedback.

4.5.2.7 Verification of Ignition System Performance

The ignition system will be verified by comparison of static test performance with specification requirements. Successful demonstration will be established by:

1. S & A arm with specified voltage and current.

2. S & A fire upon application of firing power.

3. Initiator and main Pyrogen igniter igniting properly, not exceeding design pressure levels and performing satisfactorily as pressure vessels.

4. Motor ignition within specified delay time.

4.5.2.8 Verification of Thrust Termination System Performance

The thrust termination system performance will be verified by evaluating the results of static testing on DM-3. Successful demonstration will be established by:

1. Motor case cut cleanly by the shaped charges.

2. Both parts cut within the specified simultaneity requirements.

4.5.2.9 Verification of Malfunction Detection System Performance

The malfunction detection system performance will be verified by comparison of the output signal with the motor pressure gages used during static test. Successful demonstration will be established by:

1. MDS system indicates pressure level remaining within the specified accuracy of the MDS system when compared to the test pressure gages.

2. The MDS system indicating a pressure decay within the specified accuracy at the end of action time and thrust termination on DM-3.

4.5.2.10 Verification of Instrumentation System Performance

The instrumentation system performance will be verified by comparison of the recorded output with the test stand instrumentation measuring the same event.

Successful demonstration will be established by:

1. Proper switchover upon command from ground to airborne power.

2. Airborne power battery system maintaining proper power level throughout the static test.

3. Output from the system when compared with static test instrumentation is within specification requirements.

4.5.2.11 Verification of Electrical System Performance

Successful demonstration of the electrical system performance will be established by:

1. Satisfactory distribution of power and signals to all electrical, electromechanical and ordnance items.

2. Proper fit and function of electrical interfaces among the TVC, ordnance, flight instrumentation, malfunction detection system, and simulated ground umbilical.

3. Accomplishment of timely power transfer switching functions.

4. Minimum susceptibility to RFI and EMI levels.

4.5.2.12 Ecological Requirements

Successful demonstration of compliance to acoustic and combustion products requirements will be established by:

1. Monitoring acoustic data throughout the static test duration.

2. Measuring combustion products during the SRM static test.

4.5.3 SRM Configuration

The verification and PFRT SRM configurations will be essentially the flight configuration as defined in the SRM test matrix, Table 2-1. The differences will not affect performance but will relate only to structural and ordnance items not required for static test, modifications required because of the different position of the firings, and additional instrumentation to supplement the flight instrumentation in the number of performance parameters that can be measured.

The five SRM's to be tested during PFRT will be functionally identical in configuration to the final flight configuration. Any change to this configuration shall require prior formal written approval.

The primary differences are:

4.5.3.1 Structural Differences

1. The nose cone will not be installed. The SRM will interface with a thrust collector ring.

2. A heavyweight tooling skirt will be used in place of the flight support skirt.

4.5.3.2 Ordnance Differences

1. The thrust termination safe and arm device, when used, will be mounted on special tooling on the forward end of the SRM.

4.5.3.3 Instrumentation and Electrical System Differences

1. Due to the special test tooling attachments at both the forward and aft section of the static test SRM's, flight instrumentation and instrumentation cabling will be routed within the limitations imposed and will not necessarily conform to flight configuration.

2. Batteries will be mounted in an upright position.

3. Additional electric cabling will be attached to the flight hardware/GSE connectors to monitor SRM performance parameters during static testing.

4. Additional ground measurement transducers will be incorporated on the static test SRM to monitor both system performance and SRM environment.

5. No flight instrumentation transducers will be installed on the first verification SRM firing. Subsequent test firings will utilize combinations of flight instrumentation and ground transducers to measure headend SRM chamber pressure.

6. Ground power will be provided for SRM prefire and post-fire checkout as well as for backup power during SRM test.

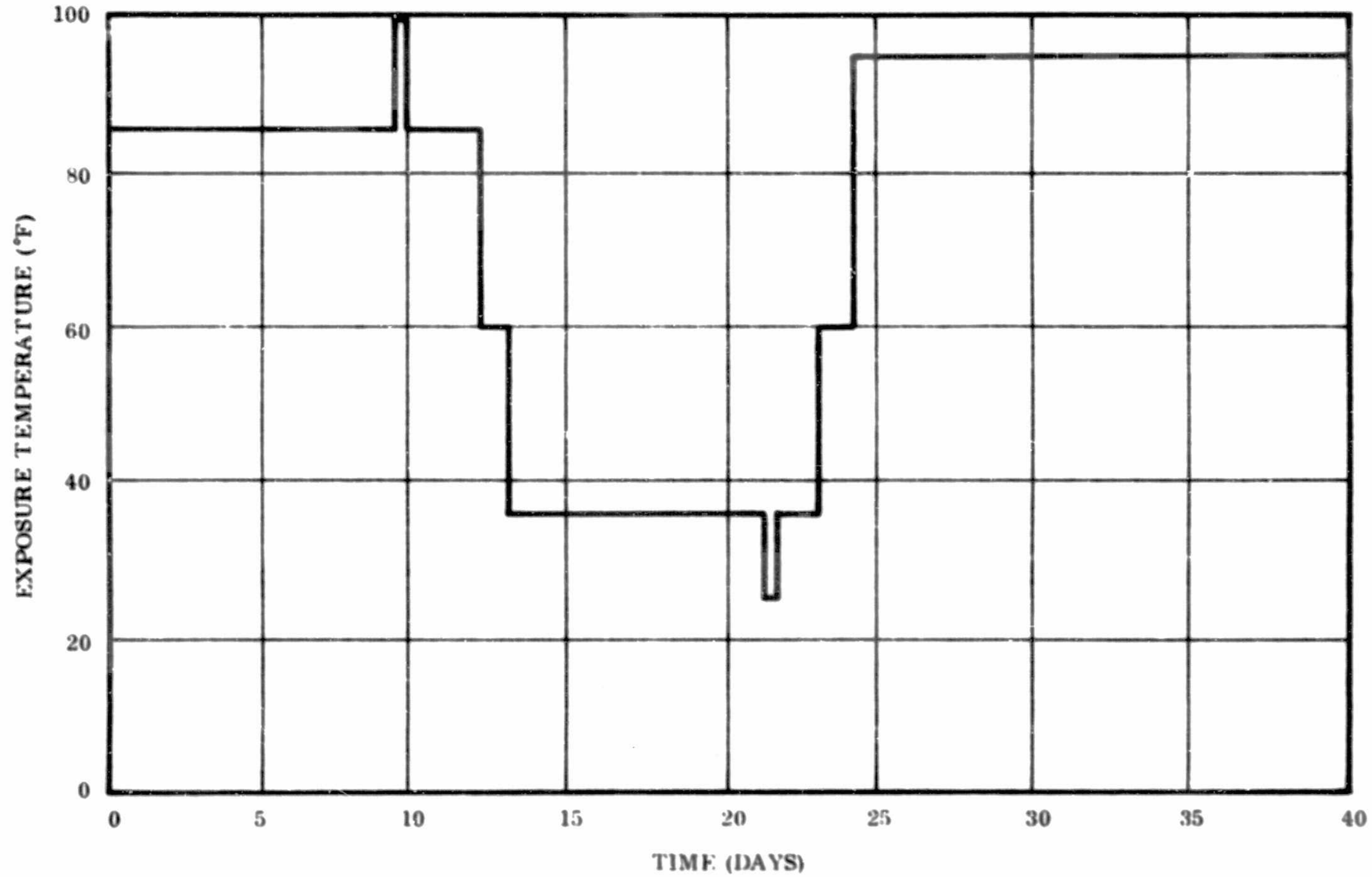
4.5.4 Grain Environmental Temperature Cycle

Solid rocket motor segments, one forward, one center and one aft, shall be temperature cycled to verify the ability of the SRM propellant grain to withstand low and high temperature environments and exposure temperatures of 25° to 100° F. Temperature cycling will be initiated immediately following completion of all manufacturing operations. The temperature cycling time is based on achieving a mean bulk temperature within ± 2 degrees of the specified basic temperature for each cycle.

The exposure temperature-time cycle to which the forward closure, center segment and aft closure will be subjected are shown in Figure 4-3. This temperature cycling pattern has been selected to produce mean bulk temperatures of 90°, 40° and 90° F at the completion of each of the three respective conditioning periods. The conditioning temperature is 5° F higher than the desired mean bulk temperature when heating the grain and 5° F lower than the desired mean bulk temperature when cooling the grain. This is necessary to achieve the desired mean bulk temperature in a reasonable length of time.

As shown in the motor test matrix (Table 2-1) one each, forward closure, center segment and aft closure, will be subjected to the temperature cycling depicted in Figure 4-3. The propellant port will be exposed during the cycling period. The time period required to achieve the desired mean bulk temperature was established by preliminary heat transfer studies. The center segment was used as the basis for these studies since it contains the maximum amount of propellant. The segment will be subjected to air velocities ranging from 5 to 8 miles per hour while in the temperature conditioning chamber. For this analysis, an air velocity of 7 mph (10 fps) was used to approximate temperature conditioning equipment capabilities. This condition results in a convective heat transfer of 2.5 Btu/sq ft-hr/° F applied to both the exterior case wall and the propellant surface.

This analysis was made assuming maximum possible temperature differences. The motor cure temperature of 135° F was used as an initial condition and the time was determined to reach a mean bulk temperature of 80°, 60°, and 40° F with forced air at 75°, 55°, and 35° F, respectively. The exposure times and temperature profiles are shown in Figure 4-4.



36175-82

Figure 4-3. SRM Segment Exposure Temperatures for Temperature Cycling

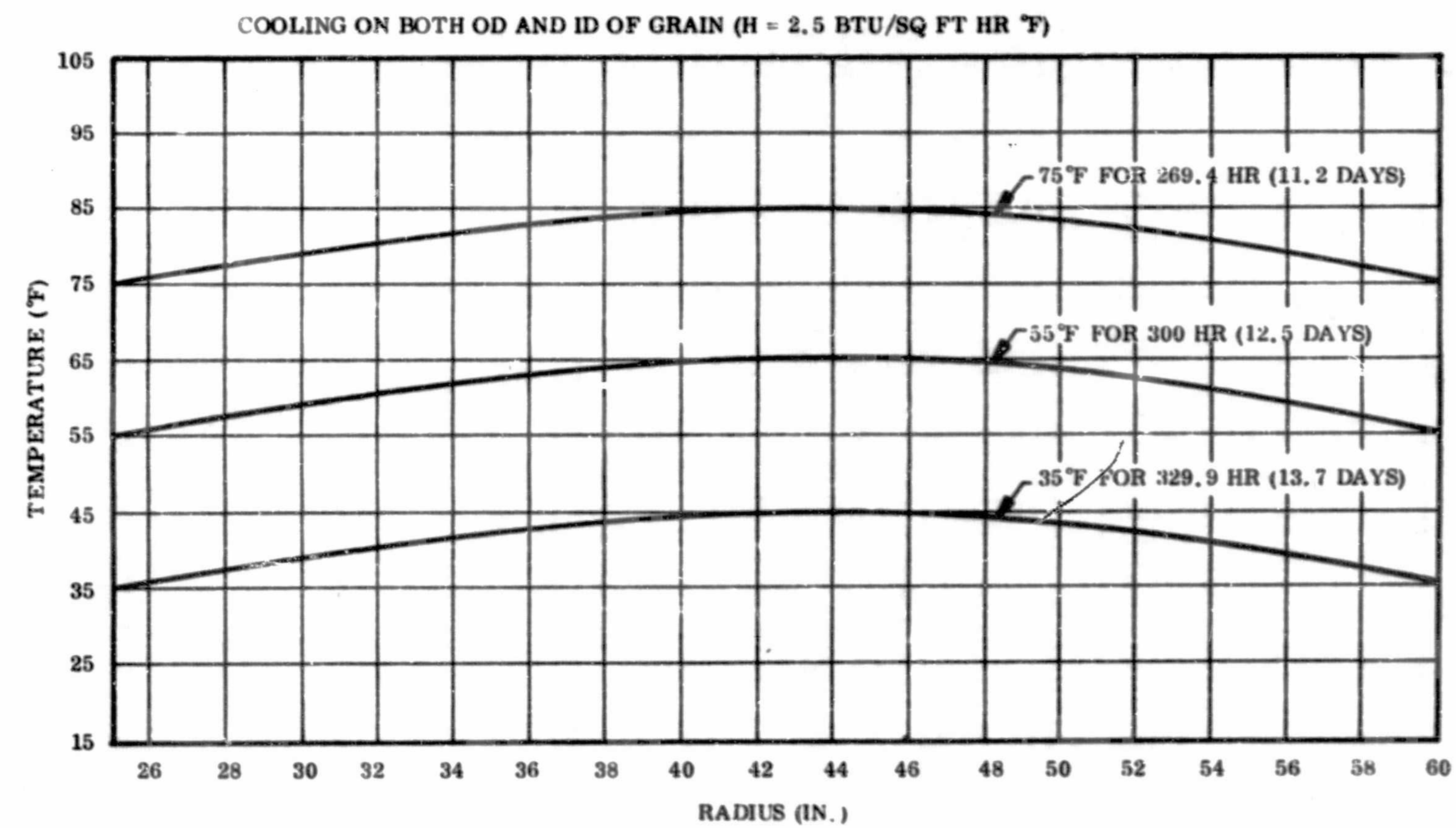


Figure 4-4. SRM Segment Grain Temperature Profile After the Time and Conditioning Temperature Shown

It should be noted that the proposed temperature cycling results in exposing a grain with a mean bulk temperature of 40°F to the high temperature environment. This condition of cold grain and warm case is considered to be the most severe condition from grain stress and bonding material temperature - strength considerations.

4.5.5 SRM Test Temperature Conditioning

All verification and PFRT motors will be temperature conditioned to 70° $\pm$ 5°F prior to static firing.

4.5.6 Transportation and Handling

4.5.6.1

Three segments, one forward, one aft, and one center, will be subjected to predicted handling shock and acceleration environments. Test data for the Minuteman Transportation and Handling (T & H) program will be used as the basis for establishing transportation and handling shocks and acceleration for the SRM. This basis for defining test limits is predicted on the similarity in transportation modes.

4.5.6.2

The Stage I Minuteman test data were obtained from a rail transportation test program for which the test course contained all conditions expected to be encountered in operational rail transportation, loading and offloading. Analyses of these data show that maximum shocks encountered occurred during conditions of railcar coupling and "humping." The shock wave form of the Minuteman motor response to railcar coupling conditions will be simulated.

4.5.7 EMI Susceptibility Survey

The EMI susceptibility survey will be made during the verification motor test program. This survey will be performed in accordance with the requirements of the Space Shuttle program for EMI compatibility.

This survey will be performed on verification motor DM-3 prior to the static test, as follows:

4.5.7.1

Deviations will be made to the SRM setup by providing "breakouts" for:

1. EMI test instrumentation

2. Simulation of ordnance items

4.5.7.2

The individual subsystems will be activated and functioned and the other subsystems functional characteristics will be monitored and recorded so that any degradation in performance from the normal which is caused by EMI can be observed. The performance normals will have been taken during individual subsystem checkout prior to the start of the EMI survey.

4.5.7.3

The flight instrumentation system, supplemented by approximately 30 additional test points, will be recorded. The recorded data tape, along with the component EMI tape, will become the basis for the analysis necessary to accomplish formal qualification.

4.5.8 SRM Static Test Facilities and Operations

SRM static tests will be conducted in the horizontal position. Test stand and motor alignment will be accomplished to assure accurate acquisition of axial and side force thrust data. SRM assembly and instrumentation will be conducted in the Thiokol static test bay. Supporting equipment for the thrust measuring system includes precision optical alignment equipment and structures for installation and operation of this equipment in the test bay.

4.5.8.1 Test Facilities

4.5.8.1.1 Thrust Test Stand

A six component, horizontal thrust test stand with a capability of measuring full forward thrust will be utilized for the static test, Ref Figure 4-3. Side thrusts, both forward and aft, as well as roll moments, also will be measured.

The axial thrust produced by the motor will be distributed to a circular thrust collecting structure that is mounted through a thrust train to the thrust block. The thrust train will consist of universal flexure and a compression load cell capable of measuring forward thrust.

4.5.8.1.2 Data Acquisition System

The data acquisition system at Thiokol Test Area shall be used to support the design confirmation test program. A total of 240 instrumentation channels are available to monitor motor and TVC performance characteristics. Of the 240 channels available, 198 are digital channels. The remaining 42 channels are frequency modulated (FM) data acquisition channels. The 240 data acquisition channels are more than adequate to meet static test data requirements.

4.5.8.2 Test Operations

4.5.8.2.1 Static Test TVC Duty Cycle

The TVC duty cycle to support the verification and PFRT motor tests will be prepared and submitted in the SRM detail test plans 30 days prior to SRM static test for NASA approval.

4.5.8.2.2 Force Measurements

Side force at the forward and aft ends of the motor will be measured by a dual bridge load cell capable of measuring both tension and compression side loads. The load cells will be located to measure the side thrust at 270 deg and attached

through a universal flexure to the side thrust blocks. The load cells and flexures will have a capacity to measure the side thrust. Measurement of the roll forces is accomplished by two dual-bridge tension or compression load cells oriented at 90 deg to the motor longitudinal axis. The two parallel load cells are located to measure vertical forces 180 deg apart. Each of the load cells is equipped with a universal flexure in the thrust train connected to the side thrust block. The thrust train will have the capacity to measure the expected vertical forces.

4.5.8.2.3 Ground Electrical Power Supply System

Direct current ground electrical power is provided for the operation of TVC electrical subsystems prior to flight battery activation and for the starting of flight hydraulic power supply.

4.5.8.2.4 Prefire Motor Systems Check

A combined systems test consisting of a dry run through the complete countdown will be conducted on the motor prior to the start of the actual countdown. Successful completion of the combined systems test including correction of all difficulties experienced during the combined systems test is a prerequisite for initiation of the actual countdown.

4.5.8.2.5 Weight and Center of Gravity Requirements

Actual component weights will be measured as each item progresses towards the completion of the manufacturing cycle. Upon completion of the manufacturing cycle, the total weight of each item will be measured. Weights will be measured with equipment capable of measuring $\pm$ 0.1 percent full scale accuracy. Weight data for the components and assembled hardware will be used with the theoretical center of gravity (cg) derived from the design drawings to establish the cg for each CI. The total motor cg will then be calculated using a digital computer program.

Post-test weights will be measured and the expended motor cg calculated. This post-test data, combined with the pretest data, will be used to correct the theoretical values of expended motor weight vs time which is required for ballistic performance analysis.

4.5.8.2.6 Data Processing

Plotted and tabulated data will be reduced and presented by using digital or analog computers with automatic plotters. The data, both directly reduced and derived, will be tabulated or plotted in a final format. The original copy of the data will be capable of being reproduced for direct inclusion in the test reports. All hand-plotted data will be plotted to the same format and style as the machine-plotted data to maintain consistency in the data presentation.

Data read directly from the test recorder tapes will be reduced in accordance with standard data reduction methods.

4.5.8.2.7 TVC Performance

The nozzle actuators are controlled by the nozzle mounted pitch and yaw control unit, which receives simulated autopilot commands, which are analog signals. The HPU will provide the hydraulic power to move the actuators.

Electrical power for the TVC system is supplied during motor test from the flight control battery assembly. Switching of vehicle power from ground power to the flight battery assembly will be accomplished by an onboard power transfer switch assembly. Facility electrical power will be suppled to the TVC system for use during TVC system checkout.

4.5.8.2.8 Electrical System Performance

Electrical connections for power, grounding, and monitoring will be provided to the motor. Facility power for prefire checkout and backup to the motor batteries during the test will be supplied to the ground power umbilical connection. Additional electrical connections will be made to supply electrical inputs and monitor performance during the test.

4.5.8.2.9 Ground Functional Interfaces

Ground functional interface tests will be conducted on verification motor DM-3 to verify the capability of the electrical cabling and interface connectors to handle the required functions. The following functions shall receive power, command and monitoring signals through the ground umbilical connector.

4.5.8.2.9.1 Ground Electrical Power

1. Gas generator squib power
2. TVC control power
3. Ordnance power
4. Instrumentation power
5. TVC hydraulic power
6. Vehicle ground monitor power

4.5.8.2.9.2 Ground Command Signals

1. TVC pitch
2. TVC yaw
3. T-T S & A safe
4. T-T S & A arm
5. T-T fire
6. Squib firing checkout fire command (control)
7. Arm and ignition

4.5.8.2.9.3 Ground Monitoring Signals

1. Safe and arm indication (ignition system)
2. Safe and arm indication (T-T system)
3. Igniter current monitor
4. Gas generator squib current
5. TVC pitch command input monitor
6. TVC yaw command input monitor
7. Ordnance battery monitor
8. Vehicle ground monitor power
9. Squib firing checkout safe indication
10. TVC battery temperature
11. Hydraulic power supply pressure
12. Flight instrumentation battery voltage

4.5.8.2.10 Space Shuttle Functional Interfaces

Space Shuttle vehicle functional interface tests will be conducted on verification motor DM-3 to verify the capability of the electrical cabling and interface connectors to handle the required functions. The following functions will receive Space Shuttle simulated power and command signals through the forward staging umbilical connector.

4.5.8.2.10.1 Airborne Electrical Power

1. Thrust termination squib power
2. SRM igniter squib power

4.5.8.2.10.2 Instrumentation Interface

The SRM will provide the following instrumentation interfaces to the Space Shuttle:

1. Signals from up to (TBD) analog channels of data conditioned from 0 to 40 millivolts (mv) dc to the Remote Multiplexer Unit (RMU).
2. Cabling for RMU component and line address.

4.5.8.2.10.3 TVC Guidance Signals

These command signals are plus or minus (TBD) vdc into a (TBD) ohms impedance per axis.

The TVC system command signals (pitch and yaw) will be monitored by flight instrumentation system circuits within the instrumentation enclosure.

4.5.8.2.11 Power Switching

The capability to switch TVC and flight instrumentation systems (FIS) from ground power to vehicle power shall be verified on DM-3 by switching through the power transfer switches. The ability to reset the ordnance monitor electronic switches after power transfer will be verified prior to the DM-3 firing and after FIS installation on the motor. The ability to transfer the TVC and FIS power sources from facility to internal (battery) power and back, and to monitor this transfer, will be verified prior to the DM-3 firing and after FIS installation on the motor.

4.5.8.2.12 Prefiring Checkout

The electrical system will be checked out after SRM assembly and prior to motor firing. Facilities power will be used for prefire checkout.

The continuity of each flight instrumentation system (FIS) data channel from signal source to recording device will be verified after FIS installation on the motors has been completed.

4.5.8.2.13 Flight Instrumentation Performance

Flight test instrumentation performance will be evaluated by review of static test data to verify:

1. Accuracy of data
2. Dynamic response characteristics

3. Low signal to noise ratio
4. Stability of transducer excitation power
5. Susceptibility to RFI and EMI levels generated by the operation of associated electromechnical equipment.

4.5.8.2.14 Post-Test Measurement and Analysis

Following each motor static test, complete visual examination and photo documentation will be accomplished. Debris pattern, if any, will be recorded and records will be made of any external anomalies discovered. Subsequent to careful visual inspection, the motor will be disassembled into major components and returned to the manufacturing area for detailed disassembly and examination.

4.6 GROUND SUPPORT EQUIPMENT VERIFICATION TESTING

Ground Support Equipment (GSE) fabricated and supplied to support the transportation of the SRM Stage component to the launch site, accomplish subassembly and checkout, and perform SRM Stage erection and checkout will be tested prior to delivery to assure that it will perform its intended function.

4.6.1 Test Description

Each design of GSE will be subjected to a qualification program appropriate for its intended use. Lifting and handling equipment will be proof loaded to demonstrate its capabilities. Electrical and electronic equipment will be subjected to calibration, vibration and/or shock loading as appropriate to its expected usage and environment. Each piece of equipment will be run through its full usage cycle to demonstrate its compatibility with interfacing SRM Stage hardware, its capability of performing its intended function, and its compatibility with other GSE, facilities and tooling in its intended operating environment.

4.6.2 Verification Completion

The GSE qualification program will be considered complete with each piece has completed its proof loading, calibration, vibration and compatibility testing program. Production acceptance requirements for GSE will be defined during the qualification program and each production item of GSE to be provided to support the GTM and FTM program will be subjected to production acceptance testing.

4.7 DETAIL TEST PLANS AND REPORTS

4.7.1 Detail Test Plans

Detail test plans will be prepared for each of the tests described in this plan. These detail plans will expand the NASA approved general test plan to the extent that all parameters of the test are clearly defined in sufficient detail such that, with the addition of the test procedures, the test can be executed.

These detail plans will be submitted to NASA 30 days prior to each individual test. Any requested change by the customer should be in the hands of Thiokol two weeks prior to the test start date.

4.7.2 Reports

The test reports for the individual tests will be submitted as required by the DRD. These include the following.

4.7.2.1 Component Verification Test Reports

Each individual test report will be submitted 30 days after the completion of the test. These reports will describe the objectives, test specimens, setup, method of test, instrumentation, test procedures, results and conclusions.

4.7.2.2 Design Verification and PFRT Motor Tests

The results of these tests will be reported as follows.

1. TWX report 24 hr after test is complete.
2. Quick-Look report 10 working days after test is complete.
3. Final report 30 days after test is complete.

5.0 OPERATIONS SUPPORT PLAN

5.1 INTRODUCTION

This Operations Support Plan establishes the concepts and defines the scope of work, the administrative and technical responsibilities and the general requirements that govern Thiokol Chemical Corporation operations at the Kennedy Space Center (KSC) during the Solid Rocket Motor (SRM) boosted Space Shuttle tests and operational flights. This plan encompasses the periods and efforts associated with the activation and continued operation of the SRM stage receive, inspect, subassemble and store (RISS) building, the vehicle assembly building (VAB) and assorted support areas during the ground test operations, the flight test operations and production flight operations.

5.2 LAUNCH SITE SUPPORT

5.2.1 Administration

Thiokol will be responsible for internal company functions such as personnel, contract administration, etc.

5.2.1.1 Working Hours and Holidays

The program schedule at KSC will be based on an 8 hr day, 5 day week. This schedule may be altered by NASA in coordination with Thiokol to meet local requirements. Holidays will be observed in accordance with management policies. Local union, State, and National regulations and statutes pertaining to working hours, scheduled and nonscheduled overtime, holidays, and working conditions will be observed. Additional shifts or overtime, when necessary in support of the assembly and test activities, will be scheduled when possible on a monthly basis. The necessary services from NASA to support overtime work will be required. Overtime estimates based upon scheduled requirements will be prepared and submitted directly to NASA.

5.2.1.2 Personal Property

Thiokol personnel assigned to KSC will be responsible for their own personal property. For removal of personal property from KSC, the owner will obtain a form and list the number of containers and contents. This form will be signed by the designee assigned to the owner's work area.

5.2.1.3 Personnel Housing

Responsibility for personnel housing rests with each organization or individual.

5.2.1.4 Visitors

Motel accommodations and travel reservations for incoming Thiokol personnel will be arranged by Thiokol.

Security escorts for visitors will be provided for all areas by the responsible organization.

5.2.2 Security

5.2.2.1 Responsibility

1. NASA will have overall responsibility for security and security control at KSC.

2. Thiokol will be responsible for security control within his assigned area.

3. Thiokol will be responsible for handling classified material which they control.

4. Thiokol will be responsible for adherence to the provisions of the Industrial Security Manual.

5.2.2.2 Security Clearance

Requests for security clearance for Thiokol employees will be submitted to the designated NASA Industrial Security Clearance Office. Thiokol will determine the eligibility of their employees for proper security clearance.

5.2.2.3 Facility Access

5.2.2.3.1 Launch Area Access

Launch Area access control is the responsibility of NASA.

1. Vehicle Access--Vehicle access within the Launch Area will be controlled by NASA. During launch day, at the discretion of NASA, official vehicles will be permitted to enter the Launch Area, or park in the area parking lot prior to safing pin removal. Vehicular restrictions will be extended to the entire blast area.

2. Launch Complex Access--Access to the Launch Complex during system tests, area checkout, etc, may be restricted at the discretion of NASA.

3. Missile Assembly Area Access

   a. Access to the SRM Assembly Area and Receiving and Inspection Area will be granted to all personnel who have the proper identification badge.

   b. Visiting personnel who do not have the proper area badge will be escorted while in the area and will be required to sign in, giving their names, organizations (or companies) and the purpose of their visits.

   c. NASA security will be provided with the names of persons authorized to sign in visitors and escort them to the various buildings as required.

   d. All personnel (operational, transient, or visiting) requiring access to RISS or Assembly Buildings will be required to obtain building access badges.

   e. Access to an assembly building during caution period operations will require the prior approval of Thiokol or NASA.

4. Postflight Critique Access--Access to the postflight critique will be limited. Thiokol will maintain additional badges for access into the critique in case of a catastrophic event.

5. Data Display Access--Data Display Area Access will be controlled by Thiokol by badges issued to each agency requiring access.

6. Data Acquisition Station Access--Access to the Data Acquisition Station will be limited to essential operations and support personnel.

5.2.2.4 Fire Prevention and Protection

1. Fire Prevention

   a. NASA will provide maintenance inspection and/or surveillance of all buildings and area fire fighting systems, fire extinguishers and/or equipment.

b. Thiokol will be responsible for all fire safety coordination with NASA Fire Department and other organizations.

c. NASA will be responsible for all fire safety in the Launch Area.

d. Thiokol will comply with KSC Fire Regulations.

2. Fire Protection

a. The NASA Fire Department will provide and be responsible for all fire fighting elements (firemen, fire trucks, hoses, ladders, protective equipment, self-contained breathing units, etc).

b. Thiokol will provide training for all auxiliary fire brigade personnel and conduct periodic fire drills.

c. Thiokol Area Supervisor will be responsible for directing fire brigade personnel in fighting a fire until the arrival of a NASA Fire Department.

d. Thiokol's Fire Supervisor will be responsible for monitoring compliance with Industrial Fire Regulations in all areas.

5.2.3 Photographic Support

NASA will provide and staff a photographic services group which will coordinate Thiokol photographic requirements. This group will maintain and operate a projection facility and film viewing room which may be used by Thiokol as necessary.

5.2.4 Reproduction and Files

NASA will provide reproduction facilities consisting of whiteprint, Xerox, and Verifax machines to accommodate Thiokol in the Launch Area. Requests for reproduction will be submitted in writing to NASA with the signature of authorized Thiokol personnel. Thiokol personnel will operate and maintain reproduction machines within their jurisdiction.

Thiokol will provide a central filing service with filing space for blueprints, engineering drawings, and specifications for supporting test operations, shop travelers, manuals, operating procedures, handbooks, etc. Thiokol will provide security cleared personnel to man the files, keep chargeout records, and replace obsolete drawings, specifications, etc, with revisions.

5.2.5 Communication

5.2.5.1 Telephone Service

Telephone service will be available to Thiokol. NASA will provide Thiokol with point-to-point communication between program facilities and other NASA facilities and surrounding communities. Arrangements will be made with NASA for the handling of long distance calls.

Leased-line telephone, telephone, teletype, and cryptographic equipment for service to home plants will be provided for and operated by Thiokol. The services of NASA-provided and -operated teletype equipment at KSC will be supplied as required for communication over commercial lines. NASA will neither maintain a copy nor make internal distribution of outgoing Thiokol messages. In addition, all copies of incoming messages will be delivered to the addressee. A telegraphic log will be maintained by NASA to record incoming and outgoing Thiokol messages by reference number, subject, date, addressee, and originator. Telegraphic message forms will be provided by NASA.

5.2.5.2 Mail

Internal unclassified mail delivery and pickup will be provided by NASA. Thiokol will provide incoming and outgoing bins in their respective areas to aid mail pickup and delivery services. Internal classified mail service will be the responsibility of Thiokol.

External mail service to and from NASA facilities, classified and unclassified will be the responsibility of Thiokol.

5.2.5.3 Public Address System

Public Address systems will be provided for safety and operations purposes. NASA will install and maintain such equipment. Use of the systems will be in accordance with approved operating procedures provided by NASA.

5.2.6 Facilities

All building and fixed installations located at KSC will be provided and maintained by NASA. Initial requirements for these buildings and installations will be generated by Thiokol and transmitted to NASA for collation and documentation. NASA will coordinate and determine the applicability of these requirements and initiate action for facility acquisition.

Facility change requests shall be submitted in accordance with the current instructions.

5.2.6.1 Parking and Yard Areas

Parking and yard facilities will be provided for use by Thiokol in each of the areas described. Parking and yard areas will be maintained by NASA. All yard maintenance requirements should be directed to NASA.

5.2.6.2 Roads and Utilities

Roads will be provided and maintained by NASA. Utilities, such as electrical power, water, steam, gas, air, sewage disposal, will be provided and maintained by NASA. Utility maintenance requirements will be directed to the NASA Facilities Office.

5.2.6.3 Hoist and Lifting Facilities

Fixed hoist and lifting facilities, where required, will be provided as part of building construction. Requests for maintenance shall be directed to NASA Facilities. Fixed hoisting equipment will be operated by Thiokol in the RISS building. Fixed hoisting equipment in the VAB will be operated by NASA. Mobile hoist and lifting equipment, not permanently assigned to the buildings involved, will be provided by NASA. Thiokol requests for mobile hoisting and lifting service shall be directed to the NASA Facilities Office.

5.2.6.4 Severable Capital Equipment

Severable capital equipment consisting of office furniture, such as desks, chairs, cabinets, etc, will be provided and maintained by NASA.

5.2.6.5 Bench Marks

Bench marks will be provided by NASA. Requests by Thiokol for bench mark changes will be made to NASA.

5.2.7 Support Shops

Shops will be provided by NASA to support Thiokol requirements. Shop requirements will be transmitted to NASA. Thiokol shop requirements include machine shop, carpentry shop, sheet metal shop, paint shop, and electrical shop. NASA personnel will man these shops. Work will be done on a work order basis. Small machine tools such as drill presses, hand saws, sanders, shears, punches, etc, will be provided by NASA in work areas.

5.2.8 Certification Laboratory

NASA will provide and operate a Calibration and Certification Laboratory. This laboratory will contain the necessary standards to certify instruments and measuring equipment supplied by Thiokol. NASA in coordination with Thiokol will provide the required standards. Thiokol Quality Control will perform equipment calibration/certification in accordance with mutually established procedures.

5.2.9 Plant Services and Housekeeping

Janitorial and housekeeping services for Thiokol occupied buildings will be provided by NASA. Janitorial and housekeeping services will be coordinated by Thiokol on a scheduled basis. Requests for off-schedule services will be directed to NASA Plant Services.

Building repair, alteration, and utility installation will be done by NASA. Requirements will be generated by Thiokol and forwarded to NASA Facilities.

5.2.10 Tool Rooms

NASA will provide and maintain tool rooms in the Vehicle Assembly Area and the Launch Area. Tool rooms will stock portable handtools and powered equipment and perishable cutting tools, plus miscellaneous shop materials such as lubricants, solvents, cleaning fluids, sandpaper, wiping towels, etc.

5.2.11 Transportation

5.2.11.1 Personnel Transportation Between Sites

NASA will provide a scheduled bus service for transportation of personnel between all areas at KSC. This system and equipment will be operated and maintained by NASA. All vehicles such as automobiles, station wagons, etc, required for nonscheduled transportation of personnel by Thiokol will be supplied, operated and maintained by Thiokol.

5.2.11.2 Miscellaneous Support Vehicles

Utility trucks, fork lifts, tow tractors, and other vehicles used to transport materials and equipment between areas will be provided, operated, and maintained by Thiokol. Launch Area peculiar equipment will be operated and maintained by NASA.

5.2.11.3 Transportation Requests

Thiokol may use NASA-operated vehicles by notifying the NASA transportation dispatcher. NASA motor pool services may be used as required.

5.2.12 Material Stores

A general purpose store will be maintained by NASA to support Thiokol. The store will contain nonaccountable items such as standard AN parts; nuts, bolts, washers, electronic tubes, resistors and capacitors, paper towels, etc.

Since Material Stores items are required for assembly and test operations, Thiokol will advise NASA of their requirements. A stock level and usage document will be prepared and distributed by NASA on a current basis.

NASA will establish procedures to insure the proper control and use of nonaccountable items. Stores issued in excess of normal anticipated usage will be coordinated through the NASA Contract Administration Office.

5.2.13 Production Control Area

A government bonded store will be maintained by NASA for the control and accountability of all Thiokol furnished (deliverable and nondeliverable) government owned supply contract property, including spares.

5.2.14 Safety

Thiokol will comply with NASA general safety standards and regulations for industrial and rocket motor safety. Thiokol will augment the general safety standards with additional safety standards that cover the particular industrial and rocket motor options.

The Primary Safety Committee will provide coordination and resolution of safety matters involving interfaces between Thiokol and NASA, including policy, procedures, and technical problems.

NASA, with the assistance of Thiokol, will prepare, maintain, and distribute a safety standard document, which incorporates all general safety standards, directives, and procedures. Proposed additions or revisions to the document will be submitted to NASA for review. Approved changes will be incorporated into the document and released for distribution by NASA. Thiokol will receive copies of the safety standards document and will be responsible for presenting all safety information to each employee and for indoctrinating each employee.

Thiokol Safety will monitor the safety effort, conduct periodic area surveys for unsafe conditions and practices, and establish and maintain safety training programs. Safety meetings will be conducted periodically by supervisors with active participation of all persons. Also, some Thiokol personnel will receive rocket motor safety instructions during indoctrination given by NASA.

Personnel will not perform unplanned operations which require the use of potentially hazardous materials and/or equipment without first obtaining a Special Work Permit from the Thiokol Safety Officer.

Each person will be responsible for observing all safety standards and procedures. Each person also will be responsible when in an operating area to report any potentially hazardous condition to a safety monitor. NASA has the overall responsibility and authority to enforce the KSC Safety Program. The responsibility for insuring compliance with safety standards will rest with each supervisor. Each area safety monitor will be constantly alert for unsafe practices and conditions and will take immediate corrective action, when possible. An Area Safety Monitor will immediately stop any operations when a potentially hazardous condition develops and will coordinate with his supervisor and with Safety for corrective action.

5.2.15 Medical Services

NASA shall provide a first aid station for treatment of Thiokol employees. Ambulance service for emergency cases will be provided on a 24 hr basis by NASA. Thiokol will provide emergency medical kits.

Thiokol will make arrangements with local area medical facilities to provide medical treatment for personnel requiring more than first aid.

5.2.16 Food Services

NASA will permit Thiokol personnel to purchase food from designated NASA messing facilities.

5.2.17 Liabilities for Government-Owned Property

Thiokol will report to NASA any damage of Government-owned property.

5.3 OPERATIONS SUPPORT

5.3.1 Introduction

This section outlines Thiokol responsibilities during Space Shuttle Operations at Kennedy Space Center (KSC).

5.3.2 Shipment

Thiokol will perform final test and inspection of ground and flight equipment prior to shipment to KSC and will insure that all items shipped to KSC are addressed correctly and required ground and test support equipment, as well as flight equipment and necessary spares, are delivered in the quantities and rates required to meet established schedules. In addition, NASA will be notified in advance of the status of all equipment shipments to KSC. NASA also will be provided the required records, logs, handling and routing instructions, design configuration, and weight and CG data for flight equipment.

5.3.3 Receiving and Visual Inspection

Thiokol will provide personnel and equipment to perform the receiving and visual inspection functions at KSC for all equipment supplied by Thiokol. Operations which will be performed include, but are not limited to, the following.

1. Inspection for external shipping damage.
2. Verification of count.
3. Identification of configuration.
4. Dimensional checks as required.
5. Physical accountability.
6. Processing of logs.
7. Providing special handling equipment as required.

5.3.4 Handling and Transportation

Thiokol will provide the required personnel and equipment, and will request routine NASA support for loading, unloading, transferring, and handling of all flight and ground equipment in and between the receiving, inspection, and storage area as well as the SRM stage buildup area. Responsibilities are as follows.

1. Segments and other components will be transported and assembled by Thiokol.

2. Subsystem ordnance will be transported and assembled by Thiokol.

3. NASA will transfer assembled Space Shuttle vehicles to and from the launch area in accordance with preplanned procedures.

5.3.5 Preassembly Inspection and Functional Test of Equipment

SRM segments and associated equipment will be inspected by Thiokol. A functional self-check of the instrumentation test set immediately before connecting to a live SRM segment will be performed.

Primary, secondary, and destruct ordnance devices will be inspected and electrically tested, if required, by Thiokol in accordance with procedures provided by Thiokol and approved by NASA.

To prevent inadvertent firing of ordnance devices, only those test instruments specifically approved by range safety will be used in conducting tests on ordnance devices, motors, or ground support equipment live ordnance circuitry.

The HPU test set shall have a functional self-check immediately before connecting to the HPU.

Records will be provided to show that each item of ground and flight equipment has been functionally tested prior to use with other equipment. Thiokol will prepare functional test procedures and specifications for this equipment. Records of testing compliance will be made available on request.

5.3.6 Assembly, Installation, and Test of Equipment

Ground and flight equipment will be installed or assembled and tested in accordance with approved schedules and procedures.

5.3.6.1 Ground Support Equipment (GSE) Responsibilities

Thiokol will be responsible for the installation, checkout and modification of all launch area GSE under the technical control of NASA. Installation and checkout of this equipment will be accomplished to drawings and procedures supplied by Thiokol and approved by NASA.

Thiokol will be responsible for the installation of all GSE furnished by Thiokol.

The requirement for retest of an item, following rework, will be coordinated with NASA representatives.

Thiokol will provide personnel and equipment to receive, inspect, install, and checkout all NASA furnished equipment. Coordination with NASA regarding NASA furnished equipment will be accomplished by Thiokol.

The mechanical and electrical checkout of equipment systems and facilities at the KSC will be accomplished using a ground test vehicle. This checkout will be performed to duplicate as closely as possible the operations performed with a flight test vehicle. The operator will conduct the checkout under the direction of NASA representatives using NASA and Thiokol supplied technical manuals.

5.3.6.2 Flight Equipment

Thiokol will accomplish all SRM Stage structural assembly, alignment, installation, placement of subsystems and components, hookup of electronics, or connections to ground support equipment. Thiokol quality control will provide the required inspections for this work.

The Space Shuttle combined systems test will consist of individual checks of each subsystem followed by an instrumentation check and a compatibility check to insure proper operation of the integrated subsystems. The configuration for this checkout is a functional interconnection of all parts except live ordnance devices. The checkout will be accomplished under the cognizance of NASA. NASA will operate the various support equipment as required and check out the vehicle subsystems in accordance with established test procedures. NASA will provide data acquisition, processing and display, and QC verification of the checkout as required.

Thiokol will perform an end-to-end test of the instrumentation subsystem. Operation and checkout of the instrumentation subsystems will be accomplished by Thiokol with the assistance of NASA as required. Thiokol's home plant will provide tapes for use in processing flight data.

Special testing in addition to that required by established test procedures (existing or new) may be necessary to satisfy requirements and to resolve anomalies. Special test preparation will be the responsibility of Thiokol. Special test procedures and results must have NASA concurrence.

A data and status review will be conducted following the combined system test to make recommendations on Space Shuttle readiness for subsequent testing and acceptance inspection.

After test acceptance by NASA Thiokol will install access panels and ordnance items.

Following acceptance of all subsystem checks, instrumentation calibrations and systems tests, a formal acceptance inspection will be accomplished. An acceptance team will decide upon acceptability of the total system relative to its

intended flight objectives and compliance with model specifications and range safety requirements. All model specification waivers and/or deviations will be approved by NASA. In general, the acceptance inspection will be a review of preflight test data and the integrated records system. NASA signoff of the acceptance summary document as prepared by Thiokol will complete the acceptance.

5.3.7 Launch Area Activities

5.3.7.1 Launch Area Buyoff

NASA will review all area modifications made since the last launch from the complex.

5.3.7.2 Launch Countdown Operations

Launch countdown operations will be conducted by NASA in accordance with approved procedures furnished by Thiokol.

The launch countdown operations for the SRM Stage follow.

1. Safe and Arm Test--Prior to launch safe and arm devices will be electrically monitored for continuity and/or armed to verify their proper operation. The test will be directed by the test conductor in accordance with approved countdown procedures.

2. Electrical Systems Test--Prelaunch testing will be conducted to establish confidence in the countdown procedure, the Space Shuttle system, and the launch equipment.

   Data will be acquired by the NASA data acquisition station via landlines.

   A data review will be conducted immediately following electric systems test. Thiokol will support NASA with analysis and recommendations concerning SRM Stage readiness for launch countdown and flight.

3. Nozzle Actuation Test--Prelaunch testing of the nozzle will be conducted to insure its operational readiness. The test will be directed by NASA in accordance with approved countdown procedures.

4. Postlaunch Activities--All postlaunch activities will be conducted in accordance with the fundamental safety plans at KSC. After each normal launch the safety inspection team and the technical inspection team will operate as specified in the launch countdown document.

5.3.8 Test Data Acquisition and Processing

The following paragraphs cover the responsibilities for acquiring, processing, displaying, storing, distributing and analyzing test data.

NASA will provide data courier and data distribution services at KSC.

NASA will provide and staff a quick-look data processing and PCM tape conversion facility as a service for Thiokol as required. In conjunction with this facility, NASA shall maintain a quick-look data display room in a secured area and a central data records system. NASA also will staff and maintain a facility for receiving and reducing engineering sequential data.

Thiokol will reduce and analyze data for the following.

1. The handling, assembly, and checkout of the SRM Stage.
2. Performance of Thiokol supplied GSE.
3. Instrumentation performance.
4. SRM performance.

NASA will be responsible for the production and delivery of the telemetry systems calibration data package (pertains to flight test and, as required, all systems test) as specified in Test Directive.

Thiokol will furnish actual weight and CG information on their components to NASA in accordance with the Mass Properties Control Plan.

Thiokol will furnish predicted SRM performance data. Drawings, configuration list, and weapon systems records will be provided by Thiokol to NASA. NASA will maintain and distribute this data as required.

Still photography for Thiokol requirements will be provided by NASA.

All Thiokol requirements for documentary photography will be coordinated with NASA. NASA will maintain records and appropriate files for reorders or display of film or photos and will maintain and operate a projection and film viewing facility for use by Thiokol.

Flight Test Data is defined as that obtained after the start of the launch countdown on launch day. Internal flight data are all test data that originate within the SRM Stage.

NASA will be responsible for recording Launch Area data obtained during a launch in accordance with Thiokol supplied procedures. Thiokol will be responsible for processing, distributing, displaying, reducing, and analyzing these data.

Flight test telemetry data will be recorded by NASA. Quick-look data will be supplied by NASA in appropriate reproducible form to Thiokol. Quick-look data may include certain engineering sequential films, some processed data, some direct recordings, and occasional documentary type films. Thiokol is responsible for the quick-look processing and display of appropriate data to NASA. NASA will determine the data to be displayed, the form to be used, and the personnel to be admitted to the display room.

5.3.9 Malfunction and Damage

In general, ground and flight equipment malfunctions will be isolated to the smallest replaceable unit and this unit replaced. Minor adjustments or repairs to support or flight equipment will be made in the area of use, if possible.

When equipment malfunction or damage occurs, Thiokol will be notified immediately. Thiokol then will schedule a period for isolation of the malfunctions within the Thiokol equipment, advising NASA on the adjustment or repair of this equipment, of the effect of the malfunction on the test, and recommendations as to where the repair or adjustment should be made. Malfunction investigations of ground and flight equipment in the Launch Area will be performed in accordance with appropriate NASA instructions. Thiokol will provide personnel to accomplish the necessary disassembly and transporting of parts to the Contractors Operations Area. All isolation, replacement, repair and retest will be recorded in accordance with appropriate NASA procedures.

Defective components will be returned to their respective functional test areas. Thiokol will be responsible for making onsite repairs or for returning the equipment to his home facility. Component packing and handling will be accomplished by Thiokol. All equipment malfunctions and repairs which affect SRM Stage assembly and test schedules will be coordinated with NASA scheduling personnel.

5.3.10 Maintenance

Maintenance is defined as servicing, lubrication, scheduled replacements, periodic calibrations, alignments, adjustments, and routine functional checks of equipment. Thiokol will monitor maintenance schedules for all Thiokol equipment. Maintenance which is critical enough to warrant revising or delaying Space Shuttle or equipment operations will be coordinated with NASA. Maintenance will be performed at the "point of use" when feasible.

Thiokol will be responsible for maintaining all equipment under Thiokol control and will accomplish the maintenance with Thiokol manpower, financial support, replacement parts, procedures, and materials.

Maintenance requirements for SRM components and GSE will be identified by performing a maintenance engineering analysis (MEA) on the SRM components and associated GSE. The MEA will identify the maintenance functions, the equipment and manpower required and approximate time and required frequency of each function.

5.3.11 NASA Equipment and Support

Equipment and services required from NASA will be established. Routine coordination with NASA concerning such equipment and services will be performed by Thiokol in support of approved working schedules.

5.3.12 Accountability

Thiokol will have the prime responsibility for accountability of NASA-owned equipment provided at KSC. Thiokol will prepare detailed accountability procedures. These procedures and accountability records shall be acceptable to NASA.

Thiokol will be accountable and responsible to NASA for the disbursement history and configuration control for all equipment provided by Thiokol. Complete records will be provided on all required items of accountability. These records will accompany the equipment and cover all operations of that equipment. Thiokol will provide NASA with advance shipping notices prior to arrival of equipment at KSC. Copies of accountability records will be provided after equipment arrives at KSC.

Thiokol will be responsible for maintaining accountability of the Launch Area facilities and support equipment under Thiokol's control.

5.3.13 Training

Thiokol will be responsible for training personnel in all operations which will be performed on the SRM Stage components and equipment. Training of personnel to insure systems effectiveness will be directed to all echelons and activities.

The training program for operations (receiving, inspection, and assembly) personnel will be initially based on an analysis of the system to determine required skill levels. This training will be accomplished by implementation of special courses.

Personnel training and/or certification programs will include, but not be limited to, the following functions and/or production and inspection processes: Nondestructive testing (magnetic particle, fluorescent, penetrant, and ultrasonic inspection), welding, brazing, soldering, electrical assembly, optical tooling and gaging, electronic measuring and test equipment, mechanical measuring techniques, special process control, sealing and potting, and statistical quality control techniques.

All personnel will receive system familiarization by informal training to insure a common departure point. As the program develops, the critical items will be analyzed to determine, by comparative analysis, if further training is required. Supplementing those data will be the Quality Audit Reports which will highlight areas requiring greater stress and consequently further training. When it is determined that tasks are so critical as to affect mission objectives, personnel certification will be required prior to assignment to the task.

Maintenance personnel for field effort will be trained in accordance with the program as required. This training will orient personnel in maintenance tasks for Thiokol maintenance responsibilities by lectures and on-the-job training (OJT). Personnel performing maintenance will be trained in specific tasks by an OJT program that will utilize engineering documentation and hardware for skill development. In addition, maintenance capabilities will be upgraded by utilization of information obtained from the Critical Items List (CIL), quality and acceptance documentation, and failure and problem data that will identify malfunctions or breakdown directly attributable to maintenance practices and techniques.

Certification of personnel is part of the overall training program. The need for Thiokol launch crew positions will be jointly determined by Thiokol and NASA and will be based on equipment and required launch functions. Where a requirement is established, a concentrated training program will be instituted and records of student progress and qualification maintained. The records and certification procedures will be made available to NASA prior to participation on the launch crew.

5.3.14 Publications

Thiokol will prepare and maintain all publications required for the SRM Stage operations.

Technical manuals will be prepared to detail all operations that will be performed. These operations include transportation and handling, receiving and inspection, assembly and checkout, and equipment and component maintenance. The various technical manuals will be identified through systems requirements and maintenance analyses. The various functions will be determined and the personnel and equipment required to fulfill the function will be identified.

Training manuals will be provided in conjunction with the training program. The training manuals will be prepared from the systems requirements and maintenance analyses.

Shop travelers will be prepared for each component or end item that is processed or used in the assembly of the SRM Stage. The shop traveler will document the operations, equipment requirements, material requirements, inspection requirements, and personnel requirements of each operation performed. The shop traveler will serve as a historical document to insure the quality of the various operations.

5.3.15 Quality Control

Thiokol will be responsible for all quality assurance aspects of the SRM Stage at the operational site up through SRM Stage selloff to NASA. The basic quality control procedures and philosophy established during the verification program at Thiokol will be extended to the GTH, FTH and production operations at the operational site.

5.3.15.1 Quality Management

Thiokol will provide at the operational site quality management whose prime objective will be to provide a final product of maximum quality and reliability at minimum cost. This objective will be accomplished through effective management of the tasks listed below.

1. Provide calibration and control of all measuring and testing devices used during inspection, assembly, test and checkout.

2. Insure that adequate receiving, inprocess, non-destructive, and final inspection tests are performed on all components, materials, GSE and final assemblies.

3. Maintain the data retention system and assure adequate documentation to support product acceptability and NASA acceptance.

4. Provide membership on the Material Review Board and assure a material review function that provides for physical control and disposition of nonconforming materials and assures that appropriate corrective action is taken.

5.3.15.2 Preparation and Maintenance of Work Instructions

Operation sheets which constitute a logbook/shop traveler will be prepared to accompany each component or assembly through each phase of assembly. The logbook will provide detailed instructions (or reference documents containing detailed procedural instructions) of the inspections to be made in every operational phase. The logbook will include the following attachments: discrepancy log, acceptance tags, reject and hold tags, material review reports, change index, and weight and balance record as required.

5.3.15.3 Operations

Quality Control will participate in the receiving inspection, testing, identification, and segregation of components and materials as discussed below.

Receiving inspection functions will be directed by the Quality Control Procedures Manual and special Quality Work Instruction and Planning Sheets. Materials and products will be inspected upon receipt to the extent necessary to assure conformance to technical requirements and to assure that no shipping damage has occurred.

All materials and components will be identified and segregated to prevent their use prior to quality acceptance. Serialization of components will be maintained in accordance with the engineering drawings and specifications. This will be accomplished to maintain and verify configuration control of the SRM.

Processing and assembly operations will be controlled through the use of the following entities: Work Instructions, Process Instructions, Quality Department Instructions, Inspection Instructions and the Shop Traveler.

Inprocess inspection will consist of, but not be limited to, the following:

1. Visual and dimensional inspection during subassembly, assembly, and testing operations.

2. Assurance and verification of compliance with process standards, specifications, and drawings.

3. Verification that materials and components incorporated into the SRM Stage have been properly inspected and accepted.

4. Immediate identification and processing of discrepant items or conditions in accordance with applicable procedures.

5. Assurance of proper identification, handling, and storage of materials, parts, and assemblies.

Quality personnel will have well defined instructions relative to the acceptance and rejection criteria. All documentation prepared and issued as instructions for examinations and acceptance of products will define the test and acceptance parameters associated with the actual examination. The documentation used to guide personnel in examination of products for acceptance will consist of the following:

1. Acceptance specification.
2. Design requirements.
3. Inspection operation sequence documents.
4. Manufacturing planning.
5. Quality instructions.

Recording of tests, inspection and examination parameters will be documented as objective evidence in the individual history logbook. In the event of variation from acceptance parameters, parts will be rejected and dispositioned in accordance with current procedures.

Inspection stamps will be used to indicate that inspection operations have been satisfactorily completed. Each issued stamp will be controlled and traceable to the individual responsible for its use. Rigid control of all inspection and special process stamps will be maintained by Quality Control. Quality Control will assure notification and cancellation of stamps which are changed, multilated, and/or returned as a result of employee termination.

Quality Assurance will be responsible to assemble all technical, manufacturing and quality assurance data necessary to prepare the SRM Stage selloff documentation. Quality Assurance shall prepare the selloff documentation and chair or co-chair the SRM Stage selloff meeting. Upon satisfactory completion of the SRM Stage selloff, Quality Assurance will be responsible for transmittal of all documentation certifying accomplishment of the selloff to Thiokol Contracts Administration.

6.0 PRODUCT ASSURANCE PLAN

6.1 INTRODUCTION

The Solid Rocket Motor (SRM) Stage product assurance program to be conducted as part of the Design, Development, Test and Evaluation (DDT & E) and production programs is described in this plan. Product assurance imposes a single integrated management discipline upon those critical program activities which experience has shown must be subject to formal discipline to assure that products will accomplish their mission. This plan specifically addresses the critical activities associated with the assurance disciplines, reliability, quality, and safety. Accordingly, all critical activities related to product assurance are identified to assure:

1. That resources in the form of documented technology, facilities and qualified personnel are developed for each activity; and,

2. That these resources are properly applied to the product to achieve customer requirements.

Management of the product assurance program is under the direction of the Space Shuttle program manager within the program management directorate. His management interests will include:

1. Development and implementation of this product assurance program, establishment of work control systems to assure that program plan requirements are communicated to all affected organizational elements, and assurance that the program tasks are adequately staffed, scheduled, and completed per schedule.

2. Assurance that all other necessary resources such as facilities, material, plans, etc, are available as required to support identified critical activities; and assurance that other than routine experience obtained during the course of this program will be communicated to those with the possible need to know, and otherwise retained as necessary to assure experience retention for subsequent projects.

3. Provisions for continuing periodic surveillance, including formal audits of product assurance activities to assure achievement of program objectives and to correct undesirable deviations or deficiencies.

THIS SPACE INTENTIONALLY LEFT BLANK

Plans for each of the three assurance disciplines comprising the principal parts of this program are contained within this plan. The Quality Assurance Plan is concerned principally with assuring the minimum number of product nonconformances. The Reliability Plan is concerned principally with minimizing the probability of a product functional nonconformance. The System Safety Plan is concerned primarily with assuring the minimum number of injuries or loss of lives and minimum loss or damage to property.

To provide maximum adaptability, the extent and frequency of revision of each plan will be tailored to its needs. Although individual plan updates are scheduled, a review for that purpose may reveal that no change is required. Subsequent release of the whole plan in a looseleaf binder will permit individual section replacement. The product assurance program manager will assure that interface of changes affecting other plans is coordinated.

6.1.1 Organization

The product assurance program will be conducted under the direction of the manager of product assurance, a member of the program management organization. He will have direct access to the program team chairman and ready access to other resource managers. The organizational relationship is indicated in Figure 6-1. The major tasks of the product assurance manager are product assurance program administration and control, identification of critical activities, and product assurance program evaluation.

6.1.2 Program Administration and Control

This preliminary plan will be completed, updated, and revised as directed by NASA, and resubmitted for approval. The tasks described in the approved plan will be subject to the functional direction and control of the program manager. He will control resource allocation to the program. Revisions to the tasks, budgets, and this program plan are also under his control. He will be either the intermediary or coparticipant in all customer discussions of product assurance related tasks.

6.1.3 Critical Activities

The program manager will assure that: critical activities within the assurance disciplines are identified, reviewed, and time phased; that initiating agencies are notified; effort and milestone events are scheduled; and that documented technology, materials, facilities, and personnel resources will be available to meet the integrated program requirements. He will develop an assurance task plan matrix identifying such elements as schedule, manhours, assigned responsibility for the task and who provides surveillance. The task plan will be coordinated with interfacing program managers and product assurance discipline managers.

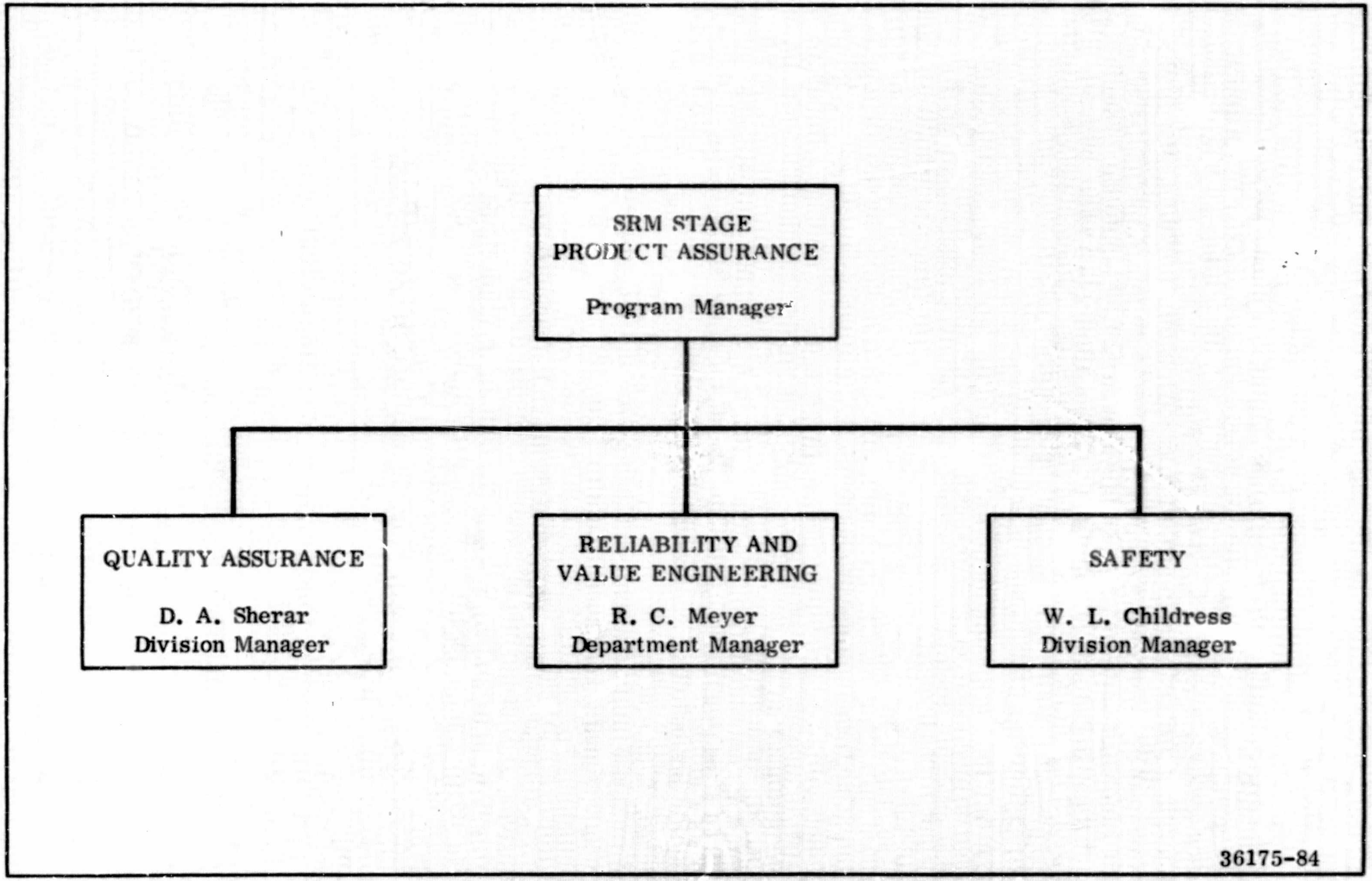


Figure 6-1. Product Assurance Organizational Relationships

6.1.4 Evaluation

The program manager will continually audit and evaluate the product assurance program. These audits are designed to obtain extempore, current, factual information as to the state of product assurance elements. Product assurance evaluation is directed to the review of audit results vs the plan at that point and program objectives. The program manager prepares and/or has prepared the necessary data in an analytical, purposeful, format designed to enable a program decision. Thus, evaluation results will be the basis for action where warranted and unilaterally attainable, or recommendations to NASA or other contractors where involved.

The audits, which are designed to provide assurance and not to pinpoint shortcomings to organizations or personnel, will include the following typical type questions.

<u>Resource Audit Considerations</u>

Have critical activities been identified to the scope and depth warranted?

Are those responsible for providing support documentation aware of that need?

Will certified personnel be required and has proper planning been accomplished?

What training and motivation have been scheduled?

What data sources are being drawn upon to capitalize upon previously obtained experience?

Will facilities be needed and if so, has their availability been established?

Are supplier resources required and has availability been established?

<u>Project Audit Considerations</u>

Has nondeliverable project data been identified, responsibility established, and distribution and retention established?

Is the project task required by the work statement?

What other commitment established the requirement?

Are the allocated resources adequate?

Is support for the task within and across organizations adequate?

Is it possible to ascertain that the task is adequate at this point?

Are the results to date in accordance with the plan?

6.2 RELIABILITY PLAN

6.2.1 Introduction

This Reliability Plan describes the reliability program to be conducted during the verification qualification, flight test, production, and delivery of 156 In. SRM Stage for the Space Shuttle. Accordingly, it specifies tasks, methods, organization, personnel and schedules for assuring achievement of SRM Stage reliability equal to or greater than the predicted values.

This plan is prepared in accordance with NHB 5300.4(1A), Reliability Program Provisions for Aeronautical and Space System Contractors, and it responds to every applicable section of that document. As specified therein, a separate program plan will be prepared for the launch site. The site reliability program plan will be combined with the quality program plan for the site and will become Appendix A of this Product Assurance Plan. All other reliability effort conducted by Thiokol inplant and in consort with listed suppliers is described in this plan.

6.2.2 Applicable Documents

The following documents form a part of this reliability plan to the extent specified herein.

6.2.2.1 NASA Publications

1. Reliability Program Provisions for Aeronautical and Space System Contractors, NHB 5300.4(1A), Glossary.

2. Elements of Design Review for Space Systems, SP 6502.

3. Parts and Materials Application Review for Space Systems, SP 6505.

4. Practical Reliability, Volumes I thru V, CR 1126 thru 30.

5. Quality Program Provisions for Aeronautical and Space System Contractors, NHB 5300.4(1B), Glossary.

6.2.2.2 Thiokol Documents

Management Policy 1008-22-065 - Reliability Programs

Management Procedure 2550-32-01001 - Reliability Programs, System Outline for

Engineering Procedure 2550-33-A400 - Engineering Reliability Program

Reliability Manual, Wasatch Division, Thiokol Chemical Corporation

6.2.3 General Requirements

6.2.3.1 Program Requirements

The level and quality of planning developed for this plan is designed to assure the attainment of reliability potential inherent in the 156 in. SRM Stage. The major tasks are described in explicit detail, are time phased, and delineate the portions which are the responsibility of other organizations. Reliability's role throughout the design, development and qualification tests and production and fabrication operations inplant are described. Typical activities include design review, product tests, product manufacture and performance test analysis, reliability assessment and reporting.

6.2.3.2 Quantitative Requirements

The Space Shuttle booster reliability requirements have not been firmly defined. A reliability failure mode and effect analysis conducted by this contractor for the preliminary SRM design, included in the volume II of this report, has led to a reliability prediction. In the absence of an imposed requirement, the predicted value becomes a requirement, with NASA's approval. The number of tests will not be sufficient to demonstrate an acceptable level of reliability in the verification and early production portions of the program. Obviously a critical failure at any point is unacceptable. Assessment of reliability conformance is discussed in a later section.

6.2.4 Reliability Program Management

6.2.4.1 Reliability Organization

The principal organization responsible for conducting the reliability program as outlined in this program plan is the Reliability and Value Engineering Department. The functional relationship of this organization to the Space Shuttle program manager is shown in Figure 6-2. The Reliability Department (Figure 6-3) is within

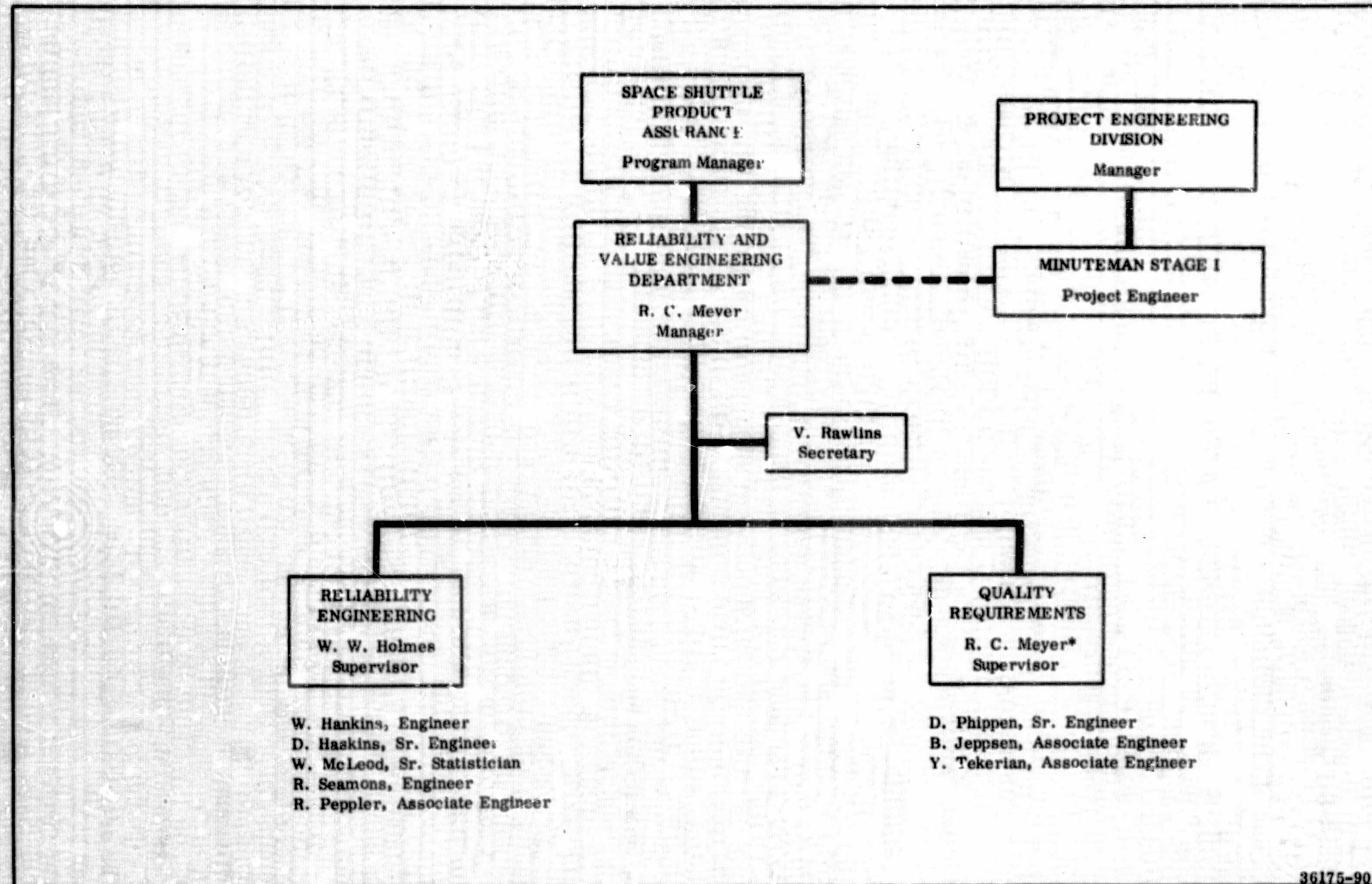


Figure 6-2. 156 In. SRM Reliability Program Organization

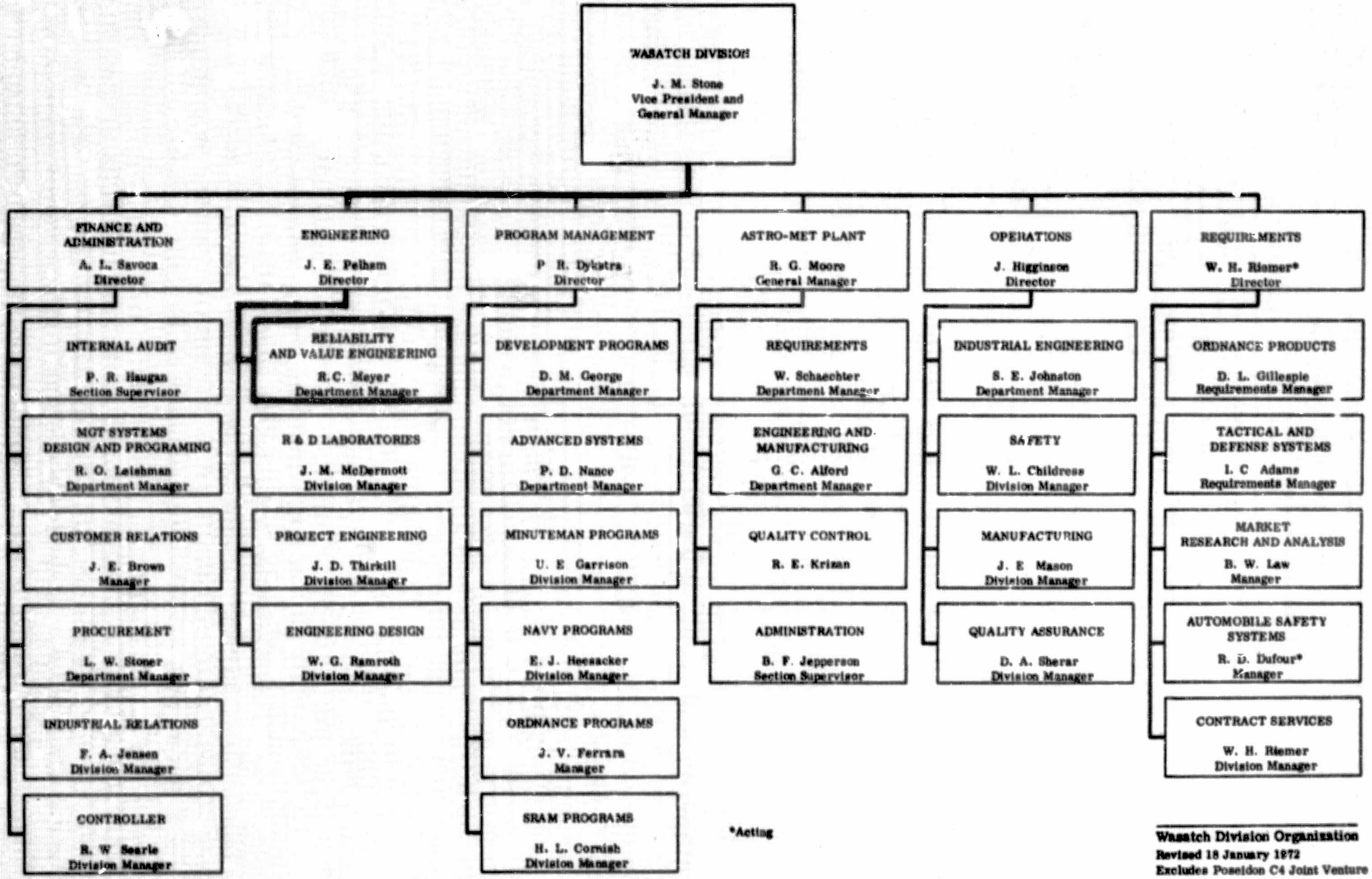


Figure 6-3. Wasatch Division Organization

the Engineering Directorate. A summary statement of responsibilities and functions of the organizations directly associated with reliability policies and their implementation for this program are as follows.

1. Program Management--The manager, Space Shuttle Product Assurance, defines requirements, ground rules and philosophy, and directs the reliability program in accordance with the contractual requirements.

2. Project Engineering--The Space Shuttle project engineer defines the scope of the engineering effort and insures efficient and timely accomplishment of engineering assignments within the established budgets.

3. Reliability and Value Engineering--The reliability function is the major portion of the Reliability and Value Engineering Department responsibility. The department manager administratively reports to the director of engineering. Program direction is provided by the program manager and the project engineer.

Technical assignments are performed within the scope of the functional charter and budgetary allocations. Program activities are planned, organized, staffed and monitored. Reliability related data are gathered, analyzed, and maintained as necessary to support the assurance of reliability achievement. The department includes two sections.

The Reliability Engineering Section's tasks include statistical analyses; reliability design analyses, including effects analyses, apportionment and predictions; reliability assessment; and motor and program status reporting.

The Quality Requirements Section identifies process generated data which need to be gathered for reliability analyses. Included are data obtained from inhouse processes and the supplier. Data review for storage, data evaluations and reporting of nonconformances and trends are also performed. Crucial process operations are monitored using the appropriate process instructions for evaluation of what is done vs instructions vs intent or obvious need for improvement.

The Organizational responsibilities for implementation of the various documents which are used in the conduct of the reliability program are listed in Figure 6-4. The organization generating the data is shown and the means of transmittal to the Reliability Department is indicated. Customer submitted documents generated by Reliability, or with Reliability, input also are indicated on the matrix.

FIGURE 6-4

DOCUMENT GENERATION AND TRANSMITTAL LIST

ITEM	PARAGRAPH REFERENCE NASA	TCC	PREPARING ORGANIZATION	FORM
Reliability Program Plan	1A201	4.1	Reliability	Program Plan*
Separate site program plans (part of RPP)	1A201-3	4.1	Reliability	Program Plan*
Reliability evaluation reports and reports of verification of corrective action completions	1A202-2	4.2	Reliability	Memo
Reliability program progress reports	1A203-2	4.3	Reliability	Reliability Report*
Reliability program control reports	1A203-3	4.3	Finance	MCCS Printout
Design specifications	1A301	5.1	Design Control	Specifications*
Reliability prediction models	1A302-1	5.2	Reliability	Assessment Report*
Functional block diagrams and apportionments	1A302-2	5.2	Reliability	Assessment Report*
Failure mode effect and criticality analyses	1A303	5.3	Reliability	Assessment Report*
Design review input packages	1A305-1a & b	5.5	Design Control	Predesign review data*
Design review meeting minutes	1A305-1d	5.5	Design Control	Design review minutes*
Design review reports	1A305-1d	5.5	Design Control	Design review report*
Reports of supplier design reviews	1A305-2	5.5	Design Control	Supplier design review*
Problem/failure reports and analysis reports	1A306-1	5.6	Reliability	Failure Reports
Problem/failure status summaries	1A306-2b	5.6	Reliability	Reliability report*
Design and process standards	1A307	5.7	Engineering Services	Various published documents
Parts, devices, and materials specifications	1A308-4	5.8	Design Control	Specifications*
Parts, devices, and materials qualification test specifications and qualification reports	1A308-5	5.8	Integration Design	Qualified Parts Reports*
Lists of parts, devices, and materials proposed for qualification testing	1A308-5	5.8	Integration Design	Qualified Parts Reports*
Project parts, devices, and materials lists	1A308-6	5.8	Integration Design	Qualified Parts Reports*
Lists of (and data on) candidates for addition to project parts, devices, and materials lists	1A308-6	5.8	Integration Design	Qualified Parts Reports*
Parts, devices, and materials application review reports	1A308-7	5.8	Integration Design	Qualified parts Reports*
Reports of failure analyses on parts, devices or materials	1A308-9	5.8	Reliability	Failure Reports

*Transmitted to NASA

Figure 6-4 (Con't)

ITEM	PARAGRAPH REFERENCE NASA	TCC	PREPARING ORGANIZATION	FORM
Reliability Evaluation Plan	1A401	6.1	Reliability	Program Plan*
Test specifications, procedures, and reports	1A402-3	6.2	Integration Design	Specs, Procedure and Reports*
Qualification Status List	1A402-2	6.2	Integration Design	Qualified Parts Reports*
Reliability Assessments	1A403	6.3	Reliability	Assessment Report*
Reliability evaluation program review reports	1A405	6.5	Reliability	Reliability Report

*Transmitted to NASA

6.2.4.2 Reliability Program Plan

As indicated in the statement of purpose and application, this document contains the plan for the Reliability Program to be conducted during the SRM Stage program. The NASA approved version of this plan will become the basis for determining contractual compliance. The planned effort is described in subsequent paragraphs, each paragraph constituting a task. A chart of task schedules with submittal milestones indicated is shown on Figures 6-5 and 6-6. The principal documented procedures which will be used for each task in the program are indicated in Figure 6-7.

6.2.4.3 Reliability Program Reviews

Periodic reviews of reliability program status at contractor and supplier facilities where reliability programs are being conducted are indicated on the schedule shown in Figures 6-5 and 6-6. These reviews are designed to evaluate the progress of the program vs the defined tasks and/or apparent needs for shifting emphasis as program progress warrants. Supplier reviews will be conducted by representatives of the Engineering, Program Management and Operations Directorates. Inhouse reviews will be conducted by members of the contractor's quality audit team. All review results will be documented and corrective action taken where indicated. Subsequent documented verification will be obtained to assure satisfactory remedy of the problems, (reference Para 2.5.6).

6.2.4.4 Reliability Progress Reporting

Progress of the reliability program will be reported per the schedule shown in Figures 6-5 and 6-6. The report will include technical progress for each program task including:

1. Evaluation of task status vs milestone.

2. Technical problems impacting reliability, and proposed or implemented corrective actions.

3. Significant program and technical decisions which impact motor reliability with some elaboration as to the probable consequences.

4. Program schedule revisions and corresponding reliability program task schedule revisions.

The Thiokol Management Cost and Control System (MCCS) will report resource expenditure vs planned rates for the reporting period and will show revised projections at appropriate milestone intervals. Other organizations expending direct effort in the support of reliability program tasks, such as data processing, also will be reflected in the MCCS.

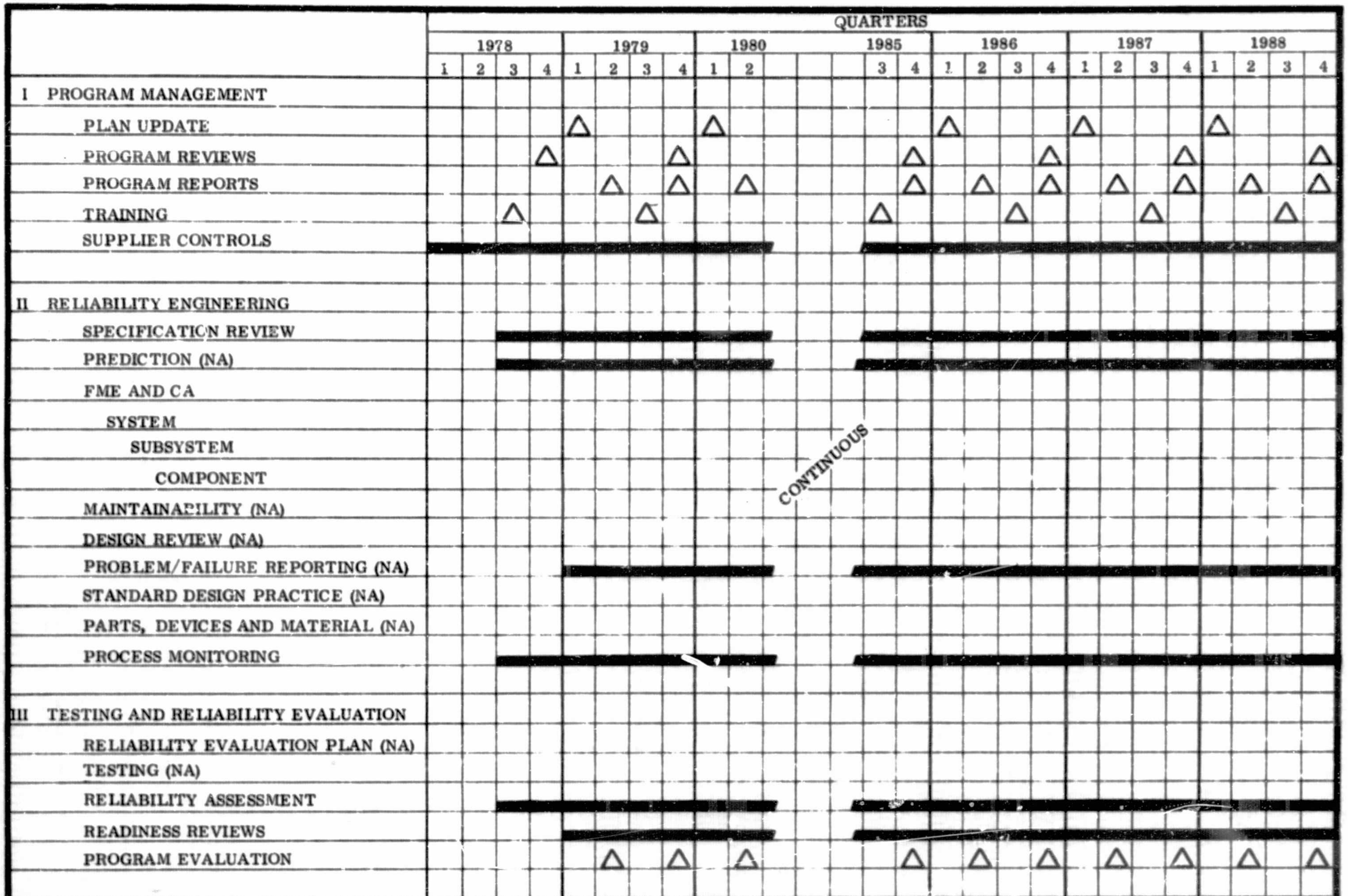


Figure 6-6. Production Reliability Program

THIS SPACE INTENTIONALLY LEFT BLANK

FIGURE 6-7

RELIABILITY PLAN
CROSS REFERENCE INDEX

TASK	REFERENCED PARA. IN NHB 5300.4(1A)	THIOKOL PROCEDURE Title	Number	Type
I PROGRAM MANAGEMENT				
Plan Update	1A201	Reliability Programs, System Outline	2550-32-01001	Management
Program Reviews	1A202	Engineering Reliability Program	2550-33-A400	Engr. Division
Progress Reports	1A203	Reliability Data Reporting	1008-34-005	Department
Training	1A204	Reliability Training	1008-34-003	Department
Supplier Controls	1A205	Supplier Reliability Assurance	1008-35-202	Department
II RELIABILITY ENGINEERING				
Specification Reviews	1A301	Design Reliability Assurance	2550-33-A401	Engr. Division
Prediction	1A302	Reliability System Model	1008-35-104	Department
FME & CA	1A303	Reliability System Model	1008-35-104	Department
System				
Subsystem				
Component				
Maintainability	1A304	Maintainability Program	2410-31-A113	Engr. Division
Design Review	1A305	Design Reliability Assurance	2550-33-A401	Engr. Division
		Design Assurance	1008-35-101	Department
Problem/Failure Reporting	1A306	Product Failure Reporting System	2240-32-00006	Management
		Product Failure Reporting System	1008-34-009	Department
Std. Design Practice	1A307			Engr. Division
Parts, Devices & Materials	1A308	System for Calling out Procured Items	2530-33-A507	Engr. Division
		Engineering Standard Part System	0808-33-A505	Engr. Division
		System for Calling Out Procured Mtl.	0808-33-A508	Engr. Division
Process Monitoring				
III TESTING & RELIABILITY EVALUATION				
Reliability evaluation plan	1A401	Reliability Demonstration	1008-35-105	Section Instruction
Testing	1A402	Requirements for Reliability Testing	1008-35-103	Section Instruction
Reliability Assessment	1A403	Reliability Evaluation & Demonstration	2550-33-A404	Engr. Division
		Reliability Demonstration	1008-35-105	Section Instruction
Readiness Reviews	1A404	Engineering Data Establishment	1008-35-206	Section Instruction
		Reliability Data Collection & Analysis	1008-35-204	Section Instruction
Program Evaluation	1A405	Reliability Programs, System Outline	2550-32-01001	Management

TABLE 6-1

SPACE SHUTTLE
VENDOR RELIABILITY CONTROL

Case Fabrication (vendor)
- Material - Metallurgical Control (subvendor)

Internal Insulation Fabrication (vendor)
- Material Control (subvendor)

Nozzle Fabrication (vendor)
- Raw Material Control (subvendor)
- Subcomponents (subvendor)
  - Raw Material Control (sub-subvendor)

Pyrogen Igniter Case Fabrication (vendor)
- Material Control (subvendor)

Igniter Case/Adapter Assembly (vendor)
- Material Control (subvendor)

Squibs (igniter) (vendor)

Safe/Arm Mechanism (vendor)
- Subcomponents (subvendor)
- Materials (subvendor)

Thrust Termination System (vendor)
- Subcomponents (subvendor)
- Explosive Materials (subvendor)

Safe/Arm Mechanism (TT system) (vendor)
- Subcomponents (subvendor)
- Materials (subvendor)
- Squibs (subvendor)

Thrust Vector Control (vendor)

Raw Rubber Composition for Flex Bearing (vendor)
- Raw Material Rubber Lot (subvendor)
  <u>if applicable</u>

TABLE 6-1 (Cont)

SPACE SHUTTLE
VENDOR RELIABILITY CONTROL

Attach Structure Fwd and Aft (vendor)

Fwd Skirt and Nose Cone (vendor)

Aft Skirt and Support (vendor)

Electrical Power and Distribution (vendor)
System Components
Materials (subvendor)

6.2.4.5 Reliability Training

As the program becomes more sharply defined, subsequent revisions of this plan will cite specific plans for training. Course content, types and number of persons to be trained also will be specified. Course development and instruction will be shared by Personnel Development and Reliability. Training will be directed toward developing an awareness of the fact that the product we deliver powers a manned flight. This attitudinal development approach will be provided to a wide audience including suppliers. While this training cannot be job specific, SRM Stage specific illustrations will be used. Illustrations which have the greatest possible impact will be sought. Available training materials, including films, will be reviewed to select the most appropriate for possible use.

More specific, job related, and discipline oriented presentations will be developed for those persons closer to the hardware. These tailored sessions will include smaller groups from departments in the Operations, Engineering and Program Management Directorates. Supplier representation at these sessions will be promoted to assist them in the development of their own inhouse courses.

Departmental training has been routinely conducted and will continue. The subjects for presentation are developed and presented by members of the department, the objective being continued professional upgrading. The scheduled presentations are short term and would become obsolete in the few weeks following preparation of this plan. The progress of all training will be reported in the periodic reporting of reliability program progress.

6.2.4.6 Supplier Control

A matrix of controlled methods by supplier will be shown in a subsequent revision to this plan, to provide an overview of the control methods employed to assure the achievement of specified quality and the reliability for parts, materials and hardware supplied to Thiokol. Those suppliers required to have formal reliability program with reporting provisions will be indicated. Also, the reviewing and/or controlling agencies for each control method, i.e., data items, tests, or inspections will be shown. The currently planned vendor obtained items are shown in Table 6-1.

6.2.5 Reliability Engineering

6.2.5.1 Design Specifications

As the design becomes more completely defined, each item of hardware will be reviewed, down to the component level, to evaluate the need for a design specification. It is currently assumed that there will be few, if any, exceptions. In the course of the review, items having functional requirements which may become a source of functional nonconformance will be identified. A list of hardware items with identified parameters of reliability interest will be transmitted to Design Engineering with a recommendation to include the parameter with limits. As specifications are generated and released for review. each will be reviewed and review comments submitted as prescribed by Engineering Directorate procedure. Each specification review will include the initial recommendations vs specification content which will encompass maintainability, human factors and safety consideration and in-use environment, including transportation and handling. The status of each specification will be monitored vs the initially recommended list to assure that all items of hardware are properly covered. In the course of the subsequent development and testing program, and continuing through qualification and production, any occasion which gives rise to the need for specification change will be carefully considered and recommended, when warranted, through the project engineer and program manager.

6.2.5.2 Reliability Prediction

The initial reliability failure modes analysis and reliability prediction have been completed based upon the initial 156 In. SRM stage design. The basis for the initial prediction is documented and includes a review of the use of the similar materials and components in other programs and in most cases includes a very extensive data base. The failure modes analysis will be updated periodically as indicated on the task schedules and will subsequently include a criticality analysis based on NASA supplied criticality factor guidelines. A functional block diagram will be developed to serve as a reliability model. Each depicted functional block in the diagram will show the reliability level predicted and required, and the block relationships as shown will indicate series or parallel relationships. The reliability model will be updated as shown on the task schedule.

6.2.5.3 Failure Mode, Effect and Criticality Analyses

The failure mode and effect analysis previously referenced has been transmitted to the Design Department and will be updated to identify the single point failures. The updated analysis will be retransmitted to design and operations personnel with the specific request that the single point failures identified be reviewed to determine whether it is possible to alter the design or devise other

control methods than those cited in the analyses to reduce the probability of occurrence. Reliability will then be responsible to assure that the identified control methods in design, manufacturing and test are responsive to the recommendations for control for each failure mode.

6.2.5.4 Maintainability in the System and Elimination of Human-Induced Failure

In the absence of a directed maintainability program the reliability organization will, as has been the practice, solicit maintainability considerations in the operations analysis conducted by the integration design group. In the course of monitoring inhouse fabrication operations, a potential for human-induced nonconformances which may result in functional nonconformances is always considered. The initial and subsequent revisions of the operations analysis which includes the system block diagrams and requirements allocation sheets will be reviewed with the analyst, using the appropriate maintainability checklists, to review the maintainability aspects of all tests, checkout, inspection, replacement, disassembly and assembly, and monitoring operations. The results of these reviews will be documented and transmitted to the program manager and project engineer with appropriate recommendations.

6.2.5.5 Design Review Program

A series of formal design reviews will be scheduled at the component, subsystem, and system levels. The attendees at each review will include at least those having direct cognizance over the parts involved. Typical attendees will include the part designer, subsystem or system designer, Manufacturing, Test, Quality Assurance, Safety and Reliability representatives. These reviews, to be conducted per schedule not yet developed, will be documented to reflect areas discussed and action indicated. The reliability organization will provide signature concurrence with each review report. The reliability organization will assist the program manager in assuring that the following NASA requirements are fulfilled.

> Followup to assure that all action items are satisfactorily completed and implemented.
>
> Compilation and submittal of a detailed description of the design review program to be used on the SRM Stage. The submitted design review program will include the appropriate procedures, design checklists, typical documentation requirements for pre-review packages and a design review schedule.
>
> Notification of NASA 15 working days prior to each scheduled review will include the pre-review package, date, time and location for the review.

Submittal of the design review meeting minutes to NASA within five working days following the review. The minutes will include the attendees, agencies represented, a statement of decisions reached, and actions that will be taken with the assigned responsibilities noted. Submittal of a summary design review report within 30 days following the review meeting, providing an account of the post-review progress, subsequent changes in plans and current schedules for completion.

The foregoing notification of design review and post-review submittal requirements will also be imposed upon suppliers who are required by contract to conduct a reliability program. No less than 10 days advance notice of a supplier design review shall be provided NASA to permit NASA personnel attendance with Thiokol personnel.

As is currently the practice, a member of the reliability organization provides representation on the Configuration Change Control Board; consequently each engineering design change made after formal design change control has been instituted, will be submitted to the change board for review, analysis and concurrence by the board members.

6.2.5.6 Problem/Failure Reporting and Correction

Because SRM stages have so few functional parts, assuring satisfactory corrective action for each functional nonconformance is no major task. The system as operated by the Reliability Department is simply a formal method for recording the occurrence of functional nonconformances, and reporting the status of investigative and corrective action with the objective of insuring adequate and timely correction of the causes contributing to the nonconformance. The requirement to record and then report regularly assures that no failures are neglected or overlooked. The system assures documentation of all functional failures occurring inplant, at the supplier's facility, and at the launch site. Each incidence of functional nonconformance occurring at these locations will be reported via the form shown in Figure 6-8. As a supplementary means of communication each report will be distributed to all those with a need to know, designers, manufacturing, quality, etc. Similarly, each supplier who produces a functional part, whether he has a supplier reliability program or not, is required to report all functional nonconformances. These reports are likewise distributed to those with a need to know.

Thiokol's technical problem status log, described in Department Instruction 1008-34-008 describes the basis for log entry of each incidence of functional nonconformance and nonconforming hardware which may result in a functional nonconformance. The procedure describes the log entry status with a continued updating until corrective action has been implemented. Technical problem status reporting will be part of the reliability program reporting and items will be carried

Thiokol/

RELIABILITY FAILURE REPORT

TC 1821 (REV 1-72)

PROGRAM	REPORT SERIAL NO.
MISSILE/TEST SERIAL NO.	REPORT DATE

FAILED ITEM IDENTIFICATION			END ITEM IDENTIFICATION (MTR/END ITEM)		
MODEL	NOMENCLATURE		MODEL	NOMENCLATURE	
P/N	S/N	VEND S/N	P/N	S/N	VEND S/N
MFGR		MFG DATE	MFGR		MFG DATE

NHA NOMENCLATURE	NHA P/N	NHA S/N	FAILURE DATE

TIME/CYCLES AT FAILURE	TEST DESCRIPTION	TEST LOCATION

SUPPORTING/REFERENCE DOCUMENTATION:

DESCRIPTION OF FAILURE:

CORRECTIVE ACTION REFERENCE:

FINAL DISPOSITION OF FAILED ITEM:

RELIABILITY REMARKS:

FAILURE CLASSIFICATION:

☐ CRITICAL (F_C) ☐ MAJOR (F_M)

ANALYSIS REFERENCE:

COORDINATION RECORD:

	(SIGNATURE)	(DATE)
RELIABILITY		
PROJECT ENGINEER		
PROGRAM MGMT		
SAFETY		

36175-112

Figure 6-8. Reliability Failure Report

in the log as reported until approximately six months after correction has been proven effective. Problems which require action beyond the scope of authority and responsibility of Thiokol will only be reported a sufficient number of times to assure that corrective action has been taken or until it becomes evident that no further action will be taken.

The technical problem status report submitted with the reliability program report will include the following type information for each problem line item entry.

1. Identification of the problem by serial number.
2. Site and test at which each failure occurred.
3. Criticality category.
4. Occurrence date and target closeout date or actual closeout date.
5. Identification of the hardware item by whatever designation is available.
6. Identification of the end item.
7. A brief description of the problem.
8. Current status of the problem and expected completion dates for indicated action items.
9. Reference to the formal documentation such as design change number which closes out the corrective action.

6.2.5.7 Standardization of Design Practices

Current design practice standards used at the Wasatch Division are defined in the Thiokol Drafting Manual, which includes the provisions of MIL-D-1000, Drawings, Engineering and Associated Lists, and other current MIL-specifications.

NASA imposed design or process standards will be added to these. As is the current practice, any changes to the aforementioned standards are reviewed by the Reliability Department. The following cited standards will be imposed upon specified suppliers.

TW-STD-125, Configuration Management, Systems, Hardware, and Component Suppliers

TW-STD-123, Configuration Management, Chemical Raw Material Supplier

Those suppliers who are required to implement a reliability program will be required to submit their standards for design practices and process specifications for review by this contractor. Typical areas for review in supplier's standardization system will include those listed on page 3-11 of the NASA reliability program provisions document.

6.2.5.8 Parts, Devices and the Materials Program

The Integration Design Group within the Engineering Directorate provides special service as advisors to the designers in the selection and application of parts, devices and materials. It's the function of this group to aid engineering and operations personnel in the selection, reduction in number of types, specification, qualification, application review, analysis of failures, stocking and handling methods, installation procedures, and the establishment of reliability and quality requirements for contract hardware. It is the function of the Reliability Department to assure that on each appropriate occasion in the RDT & E program that the foregoing considerations are an adequate part of the following cited program phases.

1. Application of existing specifications and the preparation of new specifications for parts, devices and materials.

2. Consideration of qualification status of each hardware item; review of all previous applicable test history; determination of additional tests necessary for qualification.

3. Assurance that suppliers with implemented reliability programs maintain a list of qualified parts, devices and materials. Supplier prepared qualified products list with the necessary substantiation will be compiled with the Thiokol's qualified products list and submitted initially as a candidate list to the NASA procuring agency. Subsequent inprocess candidates will be reported periodically in the reliability program reports and as each piece of hardware fulfills qualification requirements, it will be submitted as a candidate and if approved by NASA will be added to the qualified parts list for the program.

4. During the course of design reviews, the qualification status and/or need for additional requirements to fulfill qualification will be considered as a part of the predesign review. Each aspect of the intended use environment which differs from that for which the part has been qualified will be cited. Factors such as anticipated life, intended use environment, stresses, and failure history

will be referenced. This aspect of the design review will be documented and included in the design review reports.

5. The contractor's control procedures for parts, devices and materials are contained in procedures such as:

2450-32-010011	Critical Supplies; Establishment of
2440-32-01001	Raw Materials and Components, Receipt and Inspection of
2630-32-00003	Chemical Raw Materials for Production Programs; Standardization, Verification and Evaluation

These procedures specify the minimum requirements for the control of stocking and installation procedures. They also are designed to prevent degradation of parts, devices, and materials due to environments or faulty manufacturing or assembly techniques.

6. The integration design group will be advised of each incidence of failure of any hardware item currently on the qualification approved list or a potential candidate for the list. The perceived significance of the failure relative to identical parts and/or similar parts will be transmitted to the integration design group with request that they evaluate and reconsider the parts qualification status.

6.2.5.9 Process Monitoring

Material physical properties, manufacturing and process data and motor performance data measured during and after test will be stored in the Wasatch Automated Data System for current review and potential subsequent analysis. Current reviews will call for extraction via time or motors or some other characteristic in a machine plotted format. Current reviews of special interest will be presented in the project engineer/program manager.

Relatively more critical portions of the manufacturing operations will be monitored following a review of the process instructions. Each monitored segment of the process will be reported to the project engineer/program manager. Typically, these reports include noted departures, omissions in the instructions and recommendations for clarification, deletion, addition, etc.

6.2.6 Testing and Reliability Evaluation

6.2.6.1 Reliability Evaluation Plan

This section of the Program Plan describes the Reliability Evaluation Plan. Current evaluation plans include all those portions of the verification motors which remain unchanged, and all subsequent tests on the identical hardware item. Thus, scoring will be conducted by components, subsystems, systems and motor assembly. If, for example, the flexible bearing assembly remains unchanged in design from DM1 thru production go-ahead, all bearing assemblies will be included in the evaluation population. In the event of a design change of reliability significance, all tests of the previous design will be excluded. A provisional pretest exclusion may be used for the first full scale verification motor and subsequent first tests of subsystems following a design or process change to aid accumulation of data for the reliability assessment, pending stabilization of the design and fabrication process. Prior to each known motor test, a pretest declaration will be entered into a log maintained for that purpose. The motor identification, configuration, test condition, and applicability by subsystem will be shown. A subsystem may also be post-test excluded, without prior declaration of intent to exclude, if it is not exposed for at least 75 percent of the programed action time due to (1) failure of another subsystem, (2) facility malfunction, (3) instrumentation or test operator error, or (4) any other externally induced failure cause. Motors from verification, qualification, and production tests will be evaluated for applicability in the reliability assessment. Applicability of each motor will be determined beforehand based upon evaluation of the "as-built" motor. Motor applicability for the reliability assessment will be declared by subsystem for each of the subsystems. Thus a preproduction motor subsystem may be pretest excluded for reasons of nonconformance to the production configuration.

6.2.6.1.1 Reliability Assessment Method

The estimate of the delivered motors reliability, R_m, will be determined as the product of the success ratio for the subsystems.

$$R_m = \frac{S_A}{N_A} \times \frac{S_B}{N_B} \times \frac{S_C}{N_C}$$

However, because the success ratio is unity in the absence of a failure, the estimate will be obtained from the lower 50 percent confidence limit so long as no failures have occurred.

In the event of significant changes, design or process, an estimate for delivered motors will be obtained in the following manner:

$$R_m = \frac{N_1 \left(\frac{S_A}{N_A} \times \frac{S_B}{N_B} \times \frac{S_C}{N_C}\right) + N_2 \left(\frac{S_A}{N_A} \times \frac{S_B}{N_B} \times \frac{S_C}{N_C}\right)}{N_{1+2}}$$

Where N_1 is the prechange motors and N_2 the postchange motors. The affected subsystem ratios are also split into pre- and postchange quantities. Assessment of the most current configuration will simply be:

$$R_{m_2} = \frac{S_A}{N_A} \times \frac{S_B}{N_B} \times \frac{S_C}{N_C}$$

with the affected subsystem population including only the current configuration. In the absence of failures, the lower 50 percent confidence limit estimate will be used.

6.2.6.1.2 Failure Criteria

Specific motor failure criteria will be developed concurrent with the detailed motor performance specification development. In general terms, however, a critical failure of the SRM is any functional nonconformance which results in, or would have resulted in, mission failure or specifically requires change to the mission plan to accommodate the nonconformance.

6.2.6.2 Testing

The initially planned motor test program is illustrated in Figure 6-9. Test programs for all subordinate functional hardware have yet to be developed. The test plans as developed for parts, devices and materials qualification; components qualification; subsystems qualification; and systems qualification will be reviewed by the reliability organization. The review will include evaluation of the test numbers, test techniques, environmental simulation and the need and extent of overstress. As an additional part of the reliability assessment, each motor available for physical post-test examination will be evaluated for its condition relative to imminence of failure. Similarly, all data obtained from test firings and live launches will be evaluated. This accumulated variables type data will be used to provide an additional input into the reliability assessment. By selecting parameters which are indicators of the quality of performance, the reliability assessment can reflect failure probabilities not yet revealed by attributes.

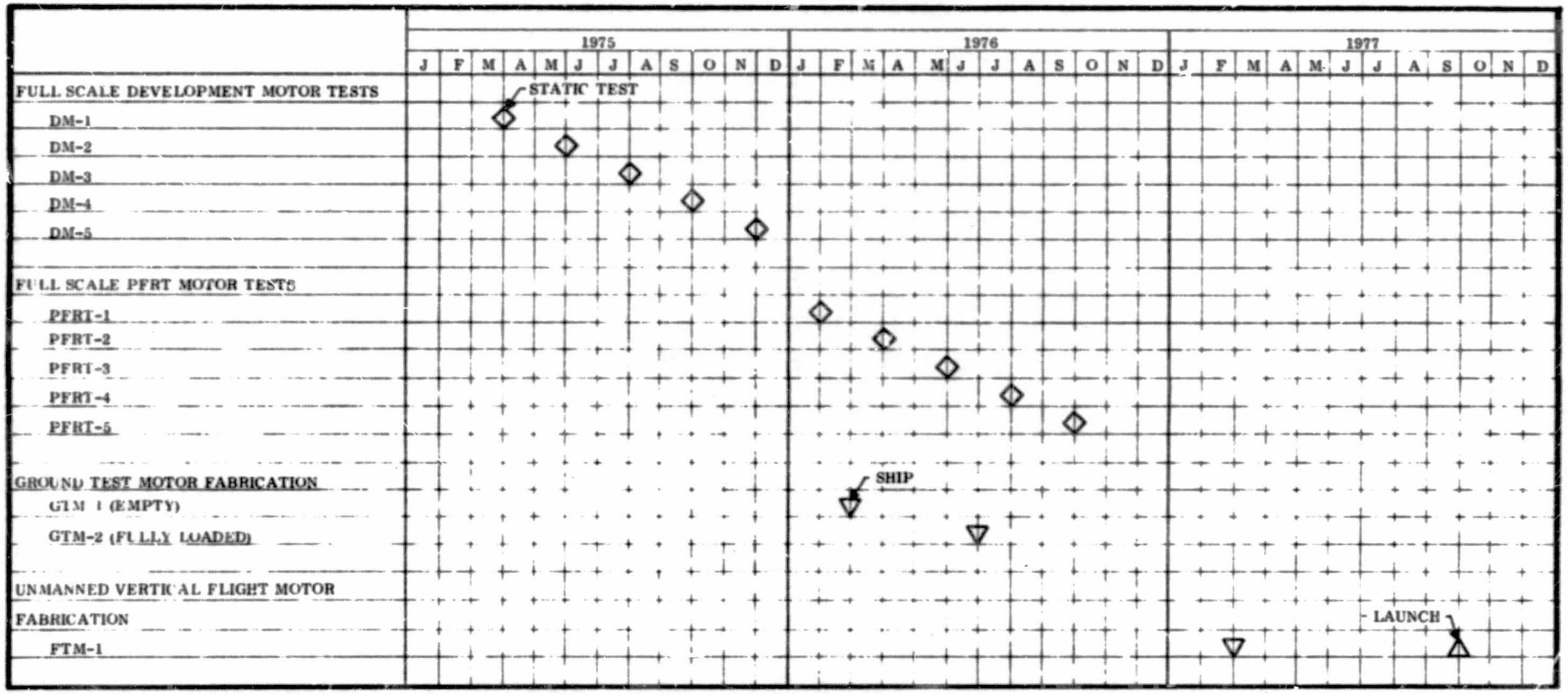


Figure 6-9. Full Scale Motor Test Schedule

6.2.6.3 Reliability Inputs to Readiness Reviews

At the outset of the program, the reliability organization will identify selected data items to be obtained from inhouse operations and the suppliers. In order to reflect all engineering data requirements, the data selected will be reviewed with the project engineering organization and with their approval, formal requests for data will be submitted to Operations and Procurement. All data thus gathered will be available for review on demand within a few days notice and selected data items will be available routinely for project milestones. Typical data items will include physical properties, functional test parameters and critical dimensional values.

6.2.6.4 Reliability Evaluation Program Reviews

As indicated in the task summary sheet, reliability program reviews, particularly reliability evaluation program reviews, will be conducted by the reliability organization. These reviews are designed to reveal progress relative to planned effort and to reveal the need for re-evaluation of the subsequently planned effort for motor reliability evaluation. The results will be documented for report transmittal to NASA and will include the current status of the evaluation program and recommendations, if any, for changes. In the event that action is indicated within the report, a responsible agency will be indicated and also a time scheduled for completion of the action.

6.3 QUALITY ASSURANCE PLAN

6.3.1 Introduction

Thiokol has a comprehensive Quality Assurance (QA) System at the Wasatch Division which was developed to meet the requirements of MIL-Q-9858 and 21549C (as modified for the Poseidon Program). This system encompasses all aspects of quality assurance from initial coordination of design requirements with engineering through final selloff of configuration items to the customer.

This Quality Plan, which describes Thiokol's Quality Assurance Program for the 156 in. SRM Stage for the Space Shuttle, follows the outline of NASA Publication NHB 5300, 4(1B), Quality Program Provisions for Aeronautical and Space System Contractors. Accordingly, it defines the quality assurance system that will be implemented upon initiation of the Space Shuttle program. Most of the aspects of Thiokol's present QA system comply with the NASA requirements; where additional controls are required, they will be implemented.

6.3.2 Quality Program Management and Planning

The responsibility for product quality ultimately rests with the General Manager who has delegated single point responsibility to the Manager, Quality Assurance. Each organization at Thiokol has specific responsibilities for the quality function. Management, Division and Department procedures establish organizational responsibilities for all quality related activities. The Manager of QA has general responsibility for assuring compliance to all QA contractual requirements and has access to top management to insure that adequate corrective action is taken. The program manager for product assurance, a member of the Program Team, has the specific responsibility for assuring compliance to the SRM Stage QA contractual requirements.

Quality Assurance will establish and maintain a comprehensive manned flight awareness program in which operating and inspection personnel will be trained and/or certified for specific tasks. Recertification will be accomplished when process changes are necessary, work assignments change, work is unsatisfactory or in all cases at specific predetermined intervals.

The QA system is defined in a manual consisting of procedures from Quality Assurance, Manufacturing, Engineering, Procurement, etc. These procedures define QA systems and are approved by the Manager of Quality Assurance.

The entire QA system is audited annually by QA supervisors not involved in the area being audited. Special audits are also performed on an unscheduled basis. The results of audits are distributed to top management and contain statements of

findings and recommendations for corrective action. Followup audits are performed to insure adequacy of the corrective actions.

6.3.3 Design and Development Controls

All aspects of the manufacturing and procurement systems will be completely documented for the Space Shuttle, including drawings, specifications, purchase orders, inspection plans, process instructions and shop travelers. Each of these will be reviewed by QA for incorporation of all pertinent design, procurement, manufacture, test and inspection criteria. Changes to each of the above documents will be approved by the Configuration Control Board chaired by Program Management, with representation from Engineering, Manufacturing, and Quality Assurance. Change submittal for customer approval will be accomplished by Program Management in accordance with contractual requirements. Incorporation of each approved change will be verified by QA and permanent records will be maintained. All documents controlling procurement and/or manufacturing will have effectivity established and will be distributed to the cognizant organizations in a timely and controlled manner.

6.3.4 Identification and Data Retrieval

Thiokol's manufacturing and quality assurance systems provide for complete data accumulation, retention and retrieval. All items used in the manufacture of configuration items will bear a unique identification number (either Part or Stock) and significant items will be further identified by serial or lot numbers. These identification numbers will be entered on all associated data and compiled in such a manner as to establish complete configuration identification. The drawing trees define where each item will be used in an assembly. Serial/lot numbers from scrapped items will not be reused for similar materials.

Indentured parts lists will be maintained as a part of the engineering data system.

Quality Assurance will maintain an organization whose sole responsibility is to review records for accuracy, verify configuration and store the records in such a manner as to facilitate a complete and accurate data retrieval.

6.3.5 Procurement Controls

Thiokol's quality assurance system maintains complete control over the procurement of materials to assure that only acceptable items are procured for use. Before any supplier can be used for a new program, he must be approved by QA. This approval is based on either a review of his history of producing like items, or by an on-site survey of his QA system by Thiokol QA personnel, or both.

End item component and raw material purchase orders will be reviewed by QA just prior to issuance to the vendor to assure that proper engineering criteria and adequate QA controls have been specified, including assurance that the supplier has been approved by QA; definition of the required supplier QA system and requirements that the supplier may not change their process without Thiokol approval; requirements for supplier data and records retention, identification and retrievability, certificate of analysis, preservation, packaging and shipping controls and age controls. Inspection Plans to be followed by the supplier, Thiokol Source Inspection Plans, Government Source Inspection Requirements, etc, will be included in each Purchase Order, as required, and their inclusion will be verified by QA.

Quality Assurance personnel will be stationed at suppliers' facilities during qualification of supplier processes and continually under the following conditions: (1) the quality of the item is controlled by processes and cannot be verified upon receipt; (2) acceptance tests are destructive or cannot be duplicated by Thiokol; or (3) poor quality history of the supplier.

The duties of all supplier representatives will be defined by means of an Inspection Plan prepared specifically for each item and approved by the Space Shuttle Senior Quality Engineer and the Program Manager. All items to be used in the end items will undergo receiving inspection. This consists, as a minimum, of review of supplier's data for completeness and accuracy to contractual requirements, proper serialization and identification, and shipping damage. Periodically the accuracy of supplier data will be verified by reinspection.

All suppliers requiring process control and who do not have resident Thiokol QA representatives will be audited periodically to assure proper process control, data accumulation, identification and retention. During the audits, reinspections will be made to verify supplier data for parameters that are uninspectable upon receipt. Deficiencies detected during these audits will be documented, and corrective action will be required. All audit reports must be approved by Quality Assurance and Program Management.

Records will be maintained of all receiving inspection and vendor generated data and will form the basis of the Vendor Quality Rating. Suppliers will be notified of substandard performance and required to take immediate corrective action. In addition, the vendors will be notified of all defects contained in their items immediately upon detection, whether detected at the supplier, during receiving inspection, during fabrication, during test or during use.

Inspection data will be interchanged between Thiokol and vendors for all propellant and liner materials and selected component measurements. All items will be clearly tagged to indicate their inspection status, i.e., accepted, hold for MRB, scrap, etc.

6.3.6 Fabrication Controls

Thiokol's control over fabrication assures compliance with contracted requirements. Shop Travelers will be used throughout the manufacturing process to define the item to be fabricated, inspections to be performed, tools to be used, characteristics to be obtained, detailed processes to be followed, environmental controls, and workmanship standards required. The Shop Travelers will contain certification of satisfactory work completion by both Manufacturing and QA personnel and will become a permanent record reflecting the quality of the part. Since all materials required for a particular manufacturing task will be drawn from stores at time of use, only acceptable materials will be available for use. Definite shelf life materials will contain the following statement on the accept tag, "Definite Shelf Life Material, DO NOT USE After 2400 Hours __(Date)__." Articles having a definite cycle life will have allowable and actual number of uses recorded on the accept tag. Materials requiring special handling are tagged "SPECIAL HANDLING REQUIRED." All manufacturing processes will be performed in environments compatible with the engineering requirements. When special environments are required, these will be noted in the Shop Traveler and controlled accordingly. Some processes involved in the manufacture and test of the Space Shuttle booster will be selected for certification by QA, Engineering and Program Management prior to being used. These processes will be certified by QA and will be performed by certified personnel, and inspected by certified inspectors. The certifications will be documented and retained on file. Recertification of personnel will be repeated periodically using a planned recertification program. Tooling used to control parameters will be certified by QA and Manufacturing to assure proper results. These tools will be reinspected periodically to assure continued accuracy. Samples of workmanship standards will be provided where they are felt to be advantageous. These standards will be jointly agreed to by Thiokol and NASA personnel.

6.3.7 Inspection and Test

All inspections and tests will be accomplished in accordance with planning defining the item to be inspected, providing for recording of configuration data and requiring objective evidence (stamp imprint) of their accomplishment. Planning will be designed to obtain the optimum economical utilization of equipment, test and materials. All static testing (of completed configuration items and qualification testing of components) will be performed in accordance with Test Plans which are based upon contractual requirements. Inprocess testing will be performed in accordance with the appropriate specifications. The Shop Traveler prepared from the test plan will be used by Test personnel to perform and document all test activities. Each configuration item will be inspected and tested in accordance with procedures unique to that item in a manner simulating, as much as possible, operating conditions. Upon initiation of a new program, QA prepares a Master Inspection Plan which lists and classifies all attributes of the configuration item. components and materials, and establishes the method and

frequency of verification of each parameter. From this Master Inspection Plan, vendor inspection plans, vendor representative inspection plans, and process inspection plans will be prepared which serve as operating documents for QA personnel and require recording of configuration data and objective evidence of compliance or noncompliance of the parameters. These completed IP's are retained and, with the completed Shop Traveler, provide the detailed configuration identification necessary for customer acceptance of the configuration item. Special Inspection Plans are prepared as required to handle specific tasks such as qualification testing either inhouse or at the vendor's facility.

Prior to commencing a test which will or may be destructive, QA will conduct a thorough record review and item inspection just as they would prior to selloff of an item. Particular attention will be given to verification of configuration and assurance that no undispositioned nonconformances exist. All static tests will be witnessed by QA to assure adherence to the Test Plan, complete and accurate recording of data and rework of nonconformances if any. Post-test activity by QA will include verification of corrective action to prevent like defects if any, and accumulation and retention of all data in a traceable, retrievable manner.

6.3.8 Nonconforming Article and Material Control

Thiokol's material review system assures that all nonconformances are reported and dispositioned. Immediately upon the detection of a nonconformance by any organization, Quality Assurance will prepare an Inspection Rejection Report (IRR): place a "Hold" tag on the item, and enter the IRR number and a "D" stamp in the planning. The IRR is a prenumbered form containing space for pertinent configuration and serialization information, description of "Should Be" and "Is" condition and a statement of cause and corrective action. The IRR is signed by the inspector and his supervisor as well as the individual(s) responsible for cause and corrective action statements. After the above steps have been completed, the IRR will be forwarded to Preliminary Material Review (QA and Engineering) for classification of defect and disposition. QA and Engineering personnel will determine if the item can be (1) returned for rework or completion of operations, (2) scrapped, or (3) returned to the supplier. If the item cannot be dispositioned via the foregoing methods, it will be submitted for full MRB action. Appropriate action to disposition the material will be taken and copies of the IRR will be distributed to operating organizations involved and to the customer. If a nonconformance will affect safety, reliability, durability, performance interchangeability, weight or the basic objectives of the contract, the nonconformance may either be dispositioned scrap by Thiokol or submitted to the contracting officer through MRB via Program Management. In all such cases, the nonconforming item is withheld for production until written NASA Contracting Officer approval is obtained. The original IRR is retained for the MRB files. The disposition will be complied with, the "Hold" tag removed, the "D" stamp cleared with an accept stamp, and the item will proceed. The QA

member of MRB will assure corrective action has or will be taken to prevent recurrence and will perform followup activities to insure effectiveness of the corrective action.

6.3.9 Metrology Controls

Thiokol maintains the most complete metrology laboratory in the Rocky Mountain area with extremely accurate environmental controls. All measuring and test equipment used in the metrology laboratory or by Manufacturing/Inspection personnel will be inspected prior to use and at scheduled intervals to assure compliance to NBS standards. (All Metrology Laboratory Standards are calibrated directly to NBS Standards at the NBS Laboratories.)

All special measuring equipment, i.e., electronic consoles, will be checked for accuracy prior to their initial use and again at scheduled intervals. Records of calibration of all inspection and metrology equipment will be maintained which show date of initial calibration, recycle calibration, repairs or adjustments made, and the individual performing the inspection. To minimize material measurement errors, devices with a measuring sensitivity 10 times greater than the tolerance band are normally used for inspection of items or calibration of the measuring device. In cases where known measuring errors might exceed contractual allowances, prior written approval will be obtained from the customer. Metrology personnel will be responsible for assuring proper handling and storage of measuring equipment and require immediate corrective action of any deficiencies detected. Each measuring device will bear a calibration sticker with a unique serial number, date of calibration, date due for recalibration and stamp of individual performing calibration. The metrology laboratory will establish and adjust calibration intervals based upon history of an item and will maintain a positive recall and pickup system for out-of-calibration devices. Records of all activities will be maintained in a permanent file. The Shop Traveler will serve as a use record of significant measuring devices used to inspect an item so that, if during calibration, a device is found sufficiently out-of-tolerance during calibration as to permit a nonconformance to go undetected, said item can be recalled.

6.3.10 Stamp Control

Thiokol maintains a complete system of stamping and tagging to identify inspection status of each article. Space Shuttle certified personnel will be given stamps with a unique design and all Space Shuttle associated tags will uniquely identify the item as "Manrated." Manufacturing and QA personnel will each have different configuration stamps. Each configuration stamp will be numbered and issued via a controlled log which will be retained as a permanent history to provide traceability of the individual performing a given function.

6.3.11 Handling, Storage, Preservation, Marking, Labeling, Packaging, Packing and Shipping

The QA system assures that positive control is maintained over handling and storage to minimize and detect nonconformances occurring in these areas. Thiokol will maintain "In-Plant Handling and Storage Manuals" which define proper methods of handling and storage of items to prevent damage. Adherence to this document is verified by inspection. Materials will be labeled and stored in such a manner as to prevent deterioration.

Detailed packing instructions developed from engineering packaging drawing requirements will be used to assure that no damage is encountered during off-site shipment. QA will monitor packing operations and must verify acceptable packing prior to shipment. Shipment controls will include verification of completion of all manufacturing operations, proper identification, packing, suitable transportation devices, and adherence to the Handling Manual. Complete documentation packages are included with each shipment as required by contract.

6.3.12 Sampling Plans, Statistical Planning and Analysis

Thiokol maintains a Quality Engineering (QE) group for statistical analysis of materials, processes, components, etc. This group detects undesirable process trends and prepares sampling plans. However, sampling will only be employed to a limited degree on the Space Shuttle program and then only when the tests are destructive. All sampling plans will have the written approval of NASA prior to implementation. Statistical analysis will be used to detect undesirable trends and prevent nonconformances in process, both inhouse and at the supplier. Charts of quality trend data will be posted in conspicuous locations to remind operators of current quality conditions.

6.3.13 Government Property Control

Thiokol maintains a complete system for accountability of Government Furnished Property. This system will provide for initial inspection upon receipt, maintenance as required, and records for identification and inspections performed. Functional testing is performed as specified in the contract prior to use.

Unsuitable Government property is documented on a "Government Furnished Property Rejection Report" and withheld from use pending Government written disposition.

6.4 SYSTEM SAFETY PLAN

6.4.1 Introduction

This System Safety Plan describes the requirements of the safety discipline. System safety is intended to minimize the loss of life, loss due to injury, and loss of property during the verification, qualification, flight test and production phases of the SRM Stage Program for the Space Shuttle.

This plan is written in response to the Safety Program Directive No. 1 - Revision A (SPD-1A) and responds to every applicable section of that document.

6.4.2 Applicable Documents

The following documents form a part of this System Safety Plan to the extent specified herein.

6.4.2.1 NASA Publications

1. Safety Program Directive No. 1 (SPD-1A)

2. Manned Space Flight Safety Program, NMI 1700.2

3. NASA Safety Manual, Volume 1, Basic Safety Requirements, NHB 1700.1 (VI).

6.4.2.2 Thiokol Publications

1. 2180-22-001 - Safety Program

2. 2180-34-5303-1 - System Safety Requirements

3. 2180-31-5202-1 - Safety Inspections

6.4.2.3 Other Publications

1. DOD 4145.26M - Contractors Safety Manual for Ammunition, Explosives and Related Dangerous Material

2. Tariff No. 23 - Hazardous Materials Regulations of the Department of Transportation.

6.4.3 Requirements

6.4.3.1 System Safety Plan (SSP)

The System Safety Plan is divided into three subsections: (1) Organization, (2) Management and Control, and (3) Program Review.

6.4.3.1.1 Organization

The System Safety Organization is within the Operations Directorate. The Manager of Safety, reporting to the Director of Operations, has the primary responsibility for conduct of the safety program. Daily operational management of system safety will be the responsibility of the Systems and Programs Supervisor. The management organization is shown in Figure 6-10.

6.4.3.1.2 Management and Control

The System Safety organization has the principal responsibility for the conduct of the safety program as defined in this plan. The scheduling, staffing and routine accomplishment of the tasks are under the control of the Manager of Safety. Budgetary and functional control will be under the direction of the Product Assurance Program Manager. Thus, emphasis of effort, priorities and redirection within the scope of the plan, or an approved revision, will be provided by the Program Manager. The currently planned System Safety tasks include the following:

1. All engineering drawings and changes will be reviewed and approved prior to releasing documents to insure compliance with all safety regulations and requirements.

2. System Safety Engineering personnel will perform preliminary, detailed hazard, and operating hazard analyses on all hazardous areas within the SRM Stage.

3. Tradeoff studies will be conducted with other Departments, i.e., Project Engineering, Manufacturing, Process and Development Engineering, Program Management, Chemical Laboratory Personnel, etc, to resolve conflicting problems and processes. Safety will insert all safety recommendations necessary to insure specific functions conform to current safety requirements.

4. Safety will review all manufacturing procedures, technical data and orders, test manuals and applicable change orders, prior to their release, to insure that they comply with all contractural safety requirements. All documents will

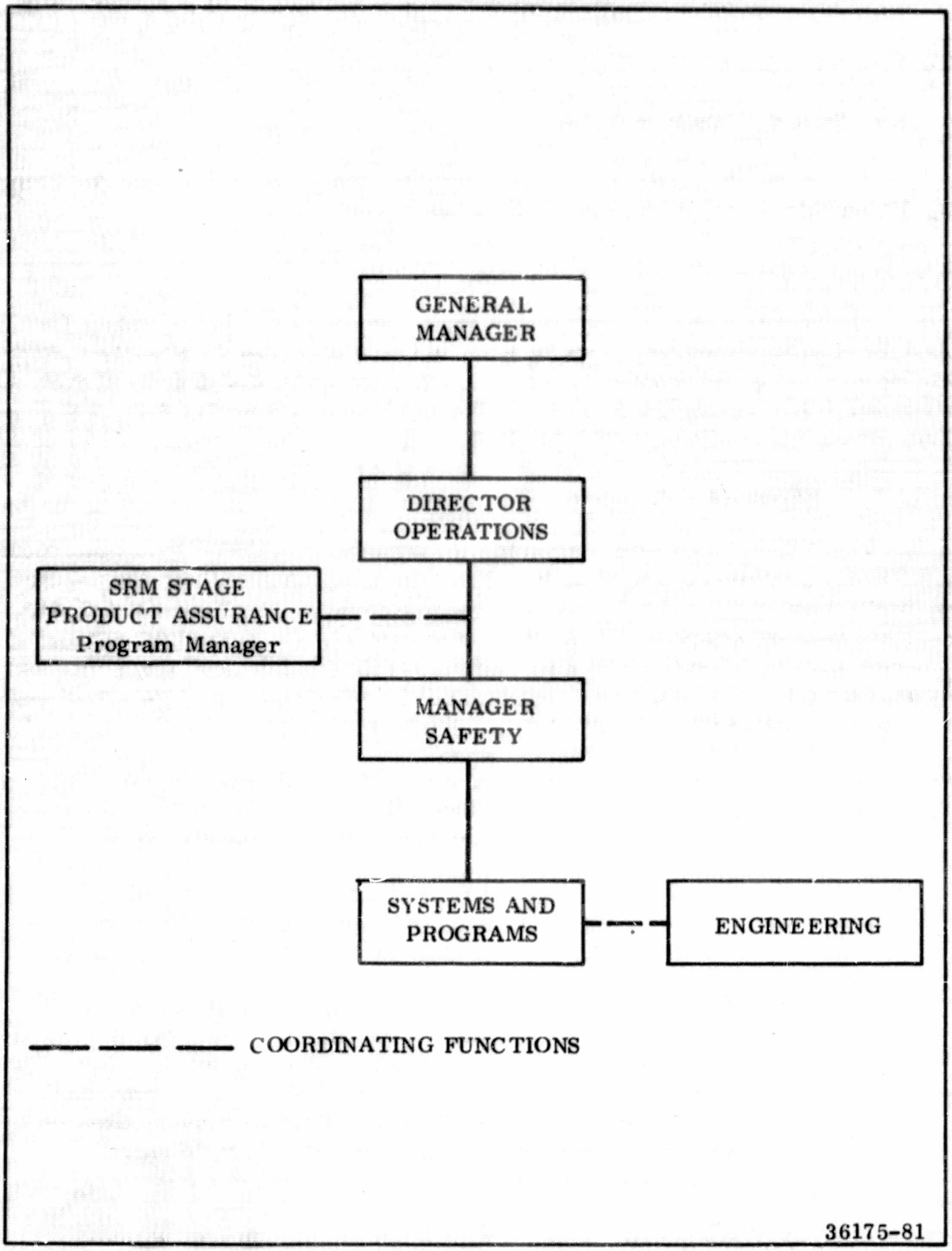


Figure 6-10. System Safety Organization

include necessary special safety instructions that will insure strict compliance with current safety standards.

5. Safety Engineering personnel will be in attendance at all tooling and equipment functional checkout meetings to insure that the parts perform as designed. All discrepancies will be documented and items will not be released until they are modified or reworked to comply with necessary specifications and drawings.

6. Facilities and operational malfunctions and incident reports will be reviewed by the Safety Department to determine cause and necessary corrective action procedures.

7. All incidents and accidents will be investigated by the Safety Department to evaluate corrective action methods. Safety will submit necessary reports to customers and management detailing circumstances for alleviating recurrence.

8. Studies will be formulated and conducted to thoroughly investigate the cause(s) of accidents. Failure data will be utilized to upgrade future like systems to insure against recurrence

9. Safety education activities will be directed toward developing increased safety awareness and a full understanding of hazardous potentials while performing operations involving propellants, explosives, and toxic chemicals. Emphasis will be placed on strict compliance to safety rules and regulations through films, posters, bulletins, manuals, and safety meetings. Safety training will be accomplished primarily by supervisory personnel through job safety instruction, with assistance from the Safety Department in such areas as explosives, propellants and other potentially hazardous items. First line supervisors will be trained in accident prevention principles and techniques. The main program objective will be to develop proper safety attitudes and conditions at Thiokol and at the launch site.

10. Active files will be maintained of all personnel injuries, accidents and incidents to insure compliance with federal regulations. Documents will be current and available for necessary reviews and inspections.

11. System Safety Engineering will perform necessary and periodic surveys of all operational functions to insure that federal industrial hygiene (noise, toxicity, etc) limitations are not being violated. Reports stemming from these surveys will be compiled and filed for future reference. All deviations will be brought into compliance through engineering methods by System Safety.

As program master schedules are developed for critical activities such as design reviews, facilities checkout, tooling validation, testing, documentation reviews, operations validation, etc, the System Safety task schedules will be expanded and more sharply defined. The current schedule is shown in Figure 6-11. This continuing process of development to reflect the program dynamics provides a current map of the state of those activities that require Safety's attention. The occurrence of changes in schedule of critical activities will be routinely learned via weekly program team meetings.

The recurring, unscheduled audits and followup of the product assurance program manager will also assure that tasks are completed per schedule.

As the hardware, facilities and tooling are being defined, specific safety oriented technical problems will be identified. To the extent possible, the impact of these problems on program requirements will be assessed; and, if a solution has been developed, a detailed solution with a program outline will be proposed. The subsequent status of all such technical problems, such as the changes implemented and their effectiveness or need for additional changes will be reported as required in the contract data requirements. Similarly, identified hazards and state of reduction will be reported until eliminated. System safety requirements identified as a result of the hazard analyses to be performed will be transmitted via inplant memorandum to the effected persons. Routinely transmitted data to affected organizations includes:

1. Hazard data.

2. Accident prevention, investigation data.

3. Safety reports.

The program manager for Product Assurance will be provided with a critical System Safety activities matrix schedule which will reflect added requirements and reveal the impact upon existing activities or the need for additional activities. Similarly, data required by System Safety will be requested via memo to the generating agency with a memo copy to the program manager to assure programing of the requirement to a scheduled completion date.

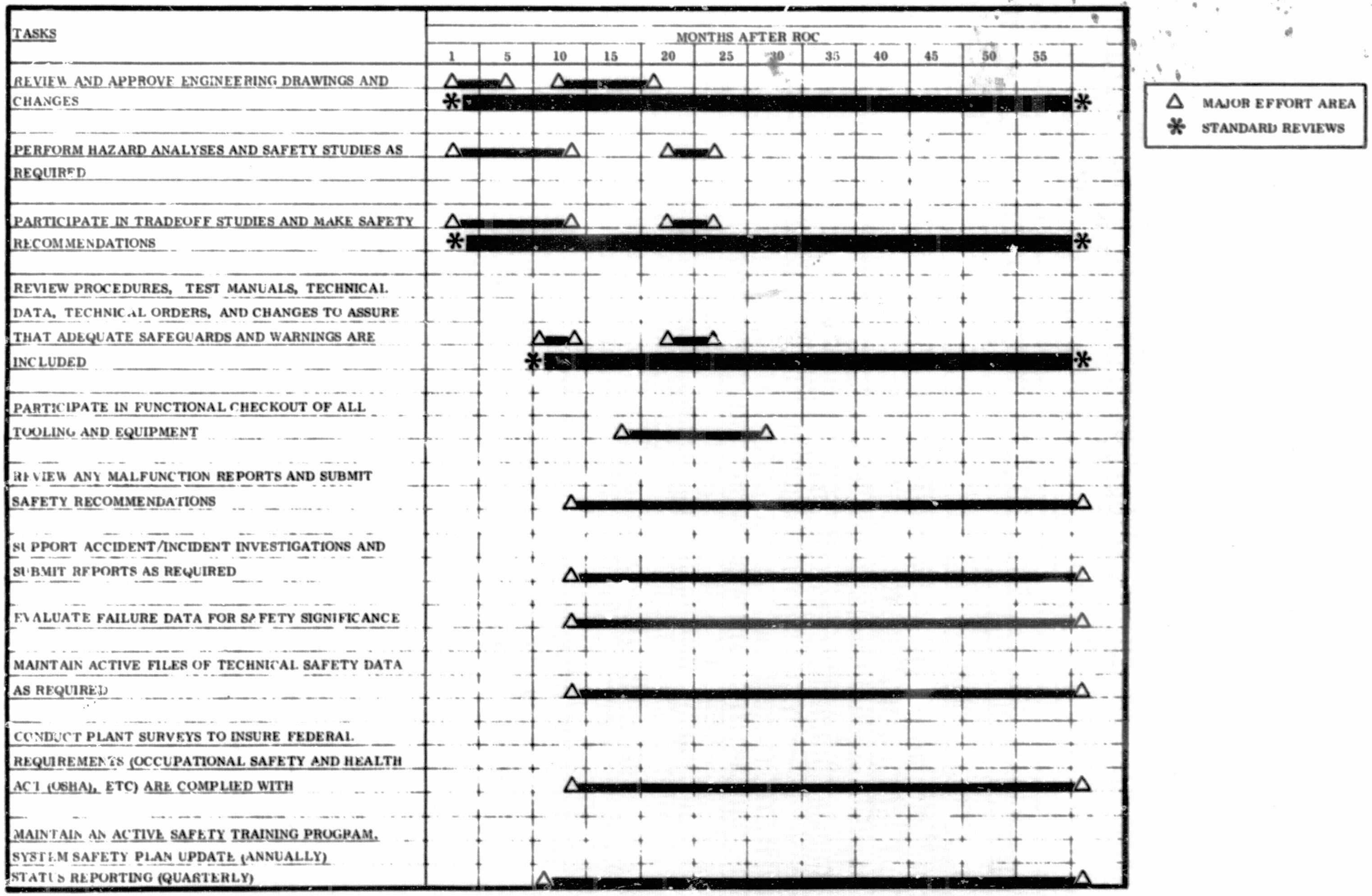


Figure 6-11. System Safety Task Schedule

6.4.3.1.3 Program Review

The System Safety Plan shall be reviewed and updated annually.

6.4.3.2 Hazard Analysis

6.4.3.2.1 Preliminary Analysis

A preliminary analysis will be conducted early in the Design, Development, Test and Evaluation (DDT & E) phase to provide a comprehensive, qualitative analysis of the system/subsystem/equipment in its intended operational environment to detect and define potential hazards. The following factors will be considered in the preliminary analysis.

1. Isolation of energy sources.
2. Fuels and propellants: their characteristics, hazard levels and quantity distance constraints; handling, storage, and transportation safety features; compatibility factors, etc.
3. Proposed system environmental constraints.
4. Use of explosive devices and their hazard constraints.
5. Compatibility of materials.
6. Effect of transient current, electromagnetic radiation, and ionizing radiation. Design of controls to prevent inadvertent activation of initiation circuits.
7. Use of pressure vessels and associated piping.
8. Documentation for safe operation and maintenance of the system.
9. Training and certification pertaining to safe operation and maintenance of the system.
10. Fire sources and protection.
11. Resistance to shock damage.
12. Long term storage.
13. Human factors.

A preliminary gross hazards analysis has been performed and is contained in Volume II of this report.

6.4.3.2.2 Detailed Hazard Analysis

The Detailed Hazard Analysis will be an expanded hazard analysis from the preliminary analysis defined above. From this analysis, the catastrophic hazards shall be eliminated or controlled.

6.4.3.2.3 Operating Hazard Analysis

The operating analysis contains the safety requirements for personnel, procedures, and equipment used in installation, maintenance, support, testing, operations and training. From this analysis, Thiokol will be able to determine (1) design changes, where feasible, to eliminate hazards; (2) inputs to the warning, caution and emergency procedures section of test operating and maintenance procedures and instructions; (3) identification of a hazard period time span and actions required if such hazards occur; and (4) special procedures for servicing, handling, storage and transportation of equipment.

6.4.3.3 Hazard Reducing Precedence Sequence

When the hazard analysis cited in Section 6.4.3.2 is completed. Safety will comply with the established order of precedence, shown below, in the reduction of hazards.

1. Insure maximum safety through the selection of appropriate design features such as fail-safe, redundancy, and increased ultimate safety factor.

2. Insure that appropriate safety devices are included in systems, subsystems, or equipment when hazards cannot be eliminated through design selection.

3. Incorporate a warning device that will indicate possible known hazards in the system. These detection units will be built so as to minimize the probability of improper personnel reaction to the signal.

4. Develop special procedures when it is not possible to reduce the magnitude of a hazard or potential hazard through either design or safety and warning devices.

5. Any residual hazards, those which cannot be controlled or isolated by procedures 1, 2, 3, or 4, shall be specifically identified to Safety and Program Management. An effort will

be made to eliminate all residual hazards and any retention of a residual hazard will be documented.

6.4.3.4 Safety Training and Certification Programs

Personnel who are required to perform any hazardous operation will receive complete instructions in the possible hazards involved, and will be issued the appropriate safety equipment. Proficiency demonstrations will be required for those performing these tasks, to assure adequacy of the training.

6.4.3.5 Human Engineering

All operational procedures (Shop Traveler, resident planning, test plans, process instructions, technical manuals, etc) for critical activities will be reviewed to identify possible changes which would minimize human error during the design, verification, manufacture, test, maintenance, and operation of the SRM system.

Consideration will be given to physiological and psychological stresses imposed by the task.

6.4.3.6 Interface with Other Program Functions

Overlaps and conflicts between the planned Safety Division effort and other program effort will be eliminated by the integration of the Safety Program with other program activity by the Product Assurance Program Manager.

6.4.3.7 Industrial Safety and Public Safety

The Safety Division will search for and identify all safety critical activities that have industrial or public safety implications. As these are identified they will be brought to the attention of the appropriate agency and a coordinated effort will be attempted.

6.4.3.8 Hazard Data Collection, Analysis and Corrective Action

Thiokol has three programs in effect for reporting, collecting, analyzing and correcting hazards. Two of these programs have been in effect for several years (C-A-R-E and ESQI) and have been effective tools for hazard reporting, analysis and corrective action. The third program (Safety Discrepancy Report) was recently implemented and is also proving to be effective. These existing programs will be utilized in Space Shuttle SRM development.

6.4.3.9 Safety Data

Repetitive design deficiencies will be prevented by utilizing safety data supplied by NASA as well as other data sources.

Safety analyses and studies conducted in compliance with NASA requirements will be delivered as required. Data generated but not delivered will be filed and maintained by Thiokol for the duration of the contract period. These data will be made available to NASA upon request.

6.4.3.10 Mishap Investigation and Reporting

All mishaps will be investigated according to appropriate NASA and Thiokol documents. The findings, conclusions and recommendations will be documented and provided to the appropriate action agencies for disposition.

6.4.4 System Safety Implementation Assurance

6.4.4.1 Margin of Safety Testing

All safety critical devices or components will have their margin of safety validated by testing. Where it is required to demonstrate the failure mode of critical components, induced failure tests will be considered.

6.4.4.2 Safety Monitoring

Safety personnel will observe all first time operations with hazardous potential, and subsequent operations as necessary to insure compliance with established safety requirements and checklists. Division Procedure 2180-31-5202.1, Safety Inspections, prescribes the frequency and method of monitoring.

6.4.4.3 Safety Audits

Safety personnel will perform audits of all functions within the SRM program; in manufacturing, at assembly, prelaunch checkout, recovery and refurbishment. These self audits will assess degree of conformance to the System Safety Plan and implementation of established safety requirements. Subcontractors will be audited as appropriate, particularly in the transportation and handling and launch site operations. Recommendations will be submitted to the affected agency and the Product Assurance program manager where necessary to insure compliance with established safety requirements.

6.4.4.4 Review of Changes

Safety analyses will be performed on proposed design and procedural changes to identify and resolve possible hazards that may be introduced into the system. Safety analysis results will be made available to the Configuration Control Board (CCB) for consideration

6.4.4.5 Postflight Evaluation

System safety personnel will participate in postflight reviews to assure that accumulated flight safety data is analyzed and utilized in preparing for future flight sequences.

6.4.4.6 Data Requirements

All safety data generated on this program will be filed, maintained and made available for review and use by authorized representatives of NASA upon request and will be provided to NASA in accordance with contractual requirements.

7.0 CONFIGURATION MANAGEMENT PLAN

7.1 INTRODUCTION

At program inception, a Configuration Management Office will be established within the Space Shuttle program management structure which will be the focal point of configuration management. The Configuration Manager will serve as chairman of the Configuration Control Board (CCB) with authority to act for the Program Manager. All changes will be coordinated with the responsible program team member to assure that all change interfaces have been considered and resolved.

7.2 ORGANIZATION

An organizational chart for the Wasatch Division of Thiokol, which illustrates the corporate structure for program management, is shown in Figure 7-1. The chart also shows the relationship of the CCB to Thiokol's other processing elements. The configuration management system at TCC consists of three organizational elements.

1. Configuration Manager--Responsible for identifying, delegating, and monitoring the achievements of configuration management requirements, and for approving changes.
2. Configuration Control Board--Provides liaison and coordination between Program Management, Engineering, Quality Assurance, Manufacturing, and Contracts and has the authority to act as an independent review and approving organization to the limit of assigned authority.
3. Design Control Section--Performs routine processing and control functions of configuration management for all programs. The section coordinates the review and release of documents and performs configuration accounting operations.

The membership of the CCB for the Space Shuttle Program is identified in Figure 7-1, which also shows the relationship of the members to the corporate structure. The lines of authority for the organizations that participate in the CCB and in other configuration management functions also are shown. The function of the CCB and the line organizations in the flow of documents through the configuration management system is shown in Figure 7-2. These flow diagrams indicate the relationship of change control to specification preparation, change preparation, engineering release, ECP preparation, and configuration accounting. As each engineering document is released, the Design Control Section records all data

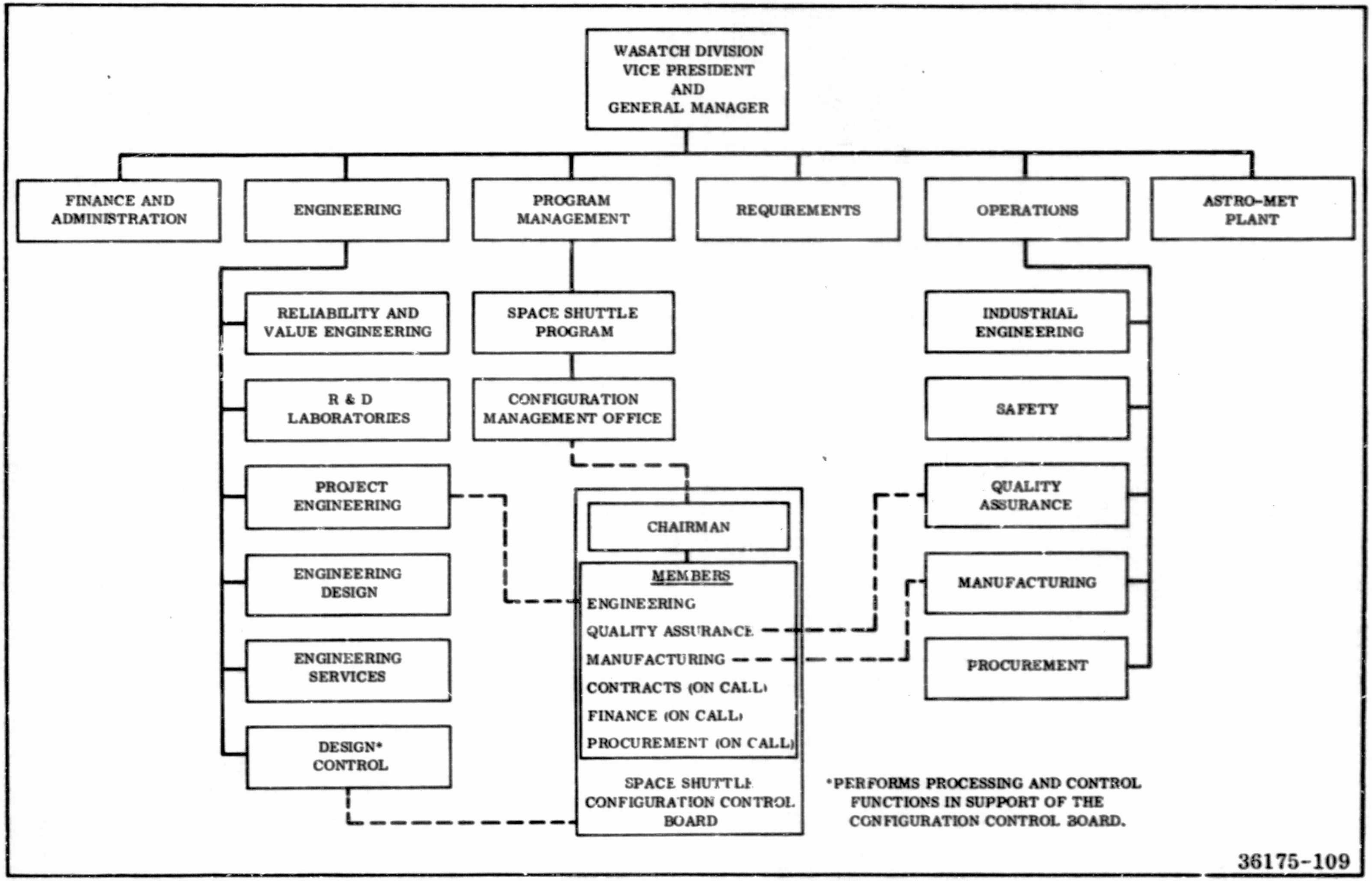


Figure 7-1. Wasatch Division Organization Showing Program Management and Relationship to Configuration Control Board

THIS SPACE INTENTIONALLY LEFT BLANK

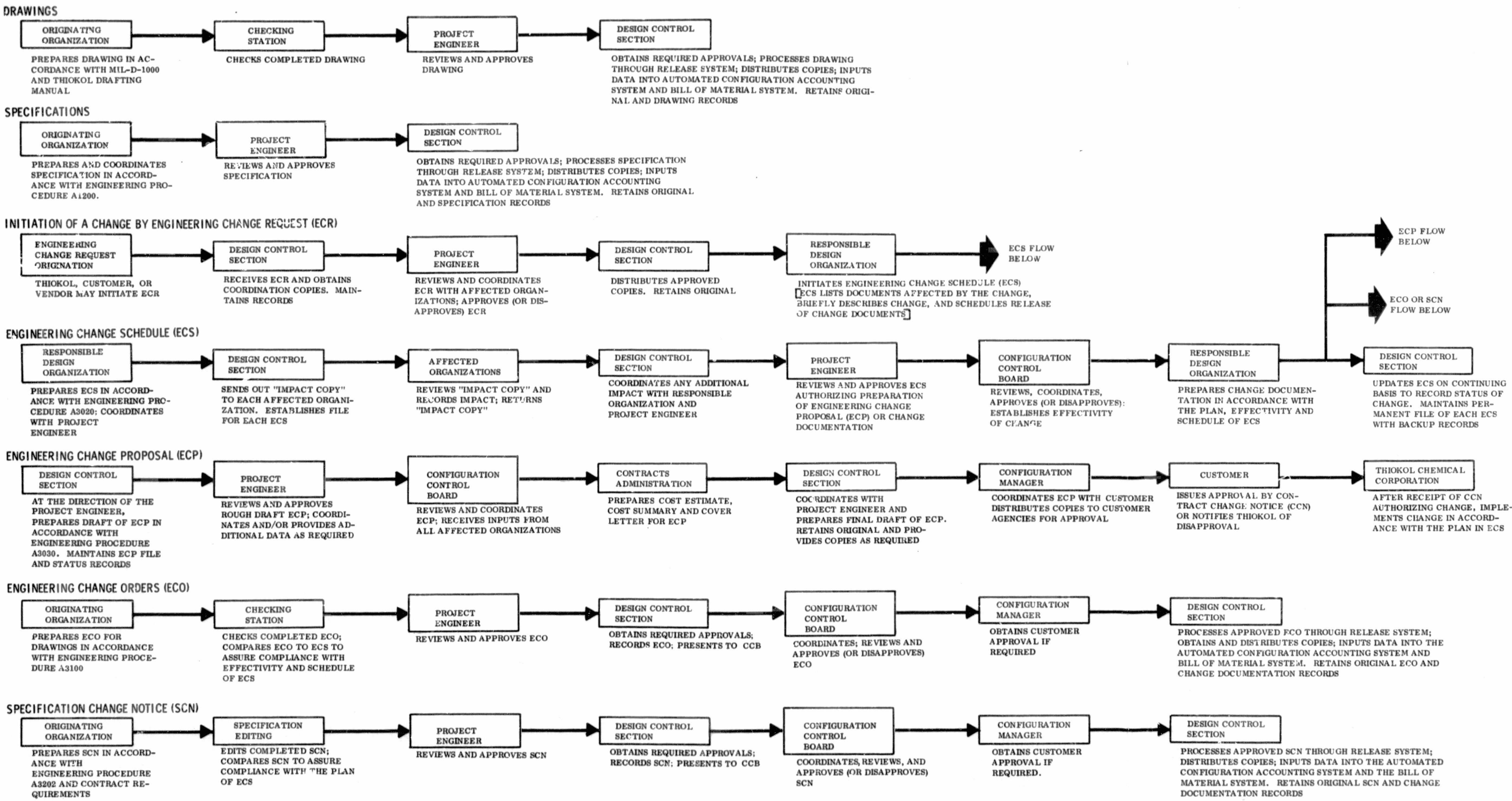


Figure 7-2. Flow of Data in Configuration Management System

which affects the configuration. These data are entered into the release records, status accounting records and into the End Item Bill of Material system.

The End Item Bill of Material system produces a manufacturing planning worksheet which reflects the "as-engineered" configuration for each assembly and subassembly. As the manufacturing planning for each item is completed, the "as-engineered" and "as-planned" configurations are compared and any differences are reported to the Project Engineer. These differences are reconciled until the planning and engineering configurations are in agreement.

Engineering and the Thiokol CCB will continually enter all changes affecting configuration (such as SCN numbers, new part numbers, and effectivities of changes) into the configuration identification system.

The Design Control Section will maintain the configuration identification records up to date at all times. This section also will maintain the specification change logs end item configuration charts, and other configuration accounting reports for inhouse and contractual requirements.

The following Thiokol policies and procedures insure implementation of all configuration management requirements.

2240-32-00004	Part Numbering, Serialization, Lot Numbering, and Name Plate Identification; Control of
2410-32-01017	Configured and Unconfigured Bills of Material and Procurement Data Lists
2520-32-00001	Engineering/Manufacturing Support Documentation; Control of
2530-32-01001	Configuration Management, System; Outline for
2530-32-01002	Engineering Changes; Processing and Implementing of
2530-32-01003	End Item; Obtaining Customer Acceptance and Selling of
2530-32-01004	End Item Specification; Development and Maintenance of
2630-32-00002	Process Changes; Control of
2660-32-00001	Product Manufacturing; Control of
0808-33-A1 thru A3500	Engineering Procedures Manual
B1000 thru B3500	Engineering Drafting Manual

THIS SPACE INTENTIONALLY LEFT BLANK

7.3 CONFIGURATION IDENTIFICATION

Configuration identification provides for the identification of the end item documentation that defines the approved functional and product baseline as established by contractual requirements. Any change to the characteristics defined on this controlled documentation must be known and approved "before-the-fact" by the Thiokol CCB.

The development of the functional configuration identification will be based upon the requirements of the Statement of Work. The functional configuration identification will be documented by a Configuration Item (CI) Specification, Part I, in accordance with contractual requirements. The preliminary Part I specification will be available for customer approval at the functional configuration audit.

The preliminary product design will be documented by the preparation of engineering drawings and specifications in accordance with contractual requirements. These drawings and specifications will be formally released through the Thiokol engineering release system and copies submitted at the Phase I design review for sponsor approval of the preliminary design. As the development effort progresses, the product definition will be expanded by releasing, and subjecting to Thiokol change control, all of the data generated.

A preliminary Configuration Item (CI) Specification, Part II, in accordance with contractual requirements, will be prepared and be available for customer approval at the physical configuration audit.

All design releases for this program will be processed through the Thiokol engineering release system and the Thiokol CCB in accordance with the Engineering Procedures Manual. Release records in accordance with contractual requirements will be prepared and maintained for the duration of the contract. These records will include all configuration identification beginning with the baseline documents and continuing with the addition of proposed and approved changes from those baselines.

Identification numbers will be applied to specifications and to drawings in accordance with contractual requirements.

Part numbering and the identification marking of each configuration item will be in accordance with contractual requirements.

The functional and product configuration will be mutually consistent and compatible. Should conflict arise between such identification, the order of precedence will be (1) functional and (2) product.

7.4 CONFIGURATION CONTROL

Performance changes subsequent to the functional configuration audit and design changes subsequent to the physical configuration audit will be submitted for customer approval prior to implementation. The Thiokol CCB will insure that all data required for the effective evaluation of a proposed change is available to the customer at the time the evaluation is made. The data provided will include an analysis on the performance of the configuration item, as prescribed by the functional configuration identification, when changes are proposed to the product configuration identification.

The preliminary product design drawings will be presented for customer approval of the preliminary design at the Phase I design review. Prior to design review, these drawings will be subject to Thiokol control only. Subsequent to customer approval of the preliminary design, design concept changes will be submitted for customer approval prior to implementation of the change. The revised drawings will be submitted within 10 days after customer approval for each change requested. Iterative design changes to component parts, which do not change the basic design concept, will be subject to Thiokol CCB control only, however, change documentation will be submitted to the customer for information within 10 days after the release of each change.

The preliminary Part I CI specification will be presented for customer approval at the Functional Configuration Audit. After customer approval of the specification, performance changes will not be implemented without prior customer approval of the change.

The preliminary Part II CI specification will be available for customer approval at Physical Configuration Audit. The final specification will have incorporated all Physical Configuration Audit and customer directed changes. Subsequent to customer approval of the specification, the specification will not be changed without prior customer approval of the change.

7.5 CONFIGURATION STATUS ACCOUNTING

Thiokol will implement and maintain configuration status accounting records in consonance with configuration identification and change control procedures. These records will identify the documentation used to define the configuration item and will provide for the integration of data to define the "as-built" configuration of each configuration item. Thiokol will maintain internal configuration records which will include, but not be limited to the following:

1. An indentured parts list prepared to make a record of the current approved configuration available on a continuing basis.

2. ECP status report that records the current status of all ECP's from inception through approval (or disapproval) to the final incorporation into drawings, specifications, and hardware.

3. "As-engineered" configuration status record for all items. This record will be kept current at all times by expanding an existing configuration accounting system.

4. "As-built" configuration status record with supporting documentation for all deviations and waivers from the "as-engineered" configuration.

7.6 CONFIGURATION AUDITS

Thiokol will insure that the functional and physical characteristics of the CI match those of the approved configuration identification.

Thiokol will conduct a Functional Configuration Audit (FCA) to insure that the configuration item has been satisfactorily developed and will perform as specified.

Thiokol will provide the test data required to accomplish this audit and will maintain the technical documentation necessary to describe the functional configuration of each CI for which the test data are verified.

Thiokol will conduct a Physical Configuration Audit (PCA) on a unit of the CI selected jointly by the customer and Thiokol. This configuration audit will be conducted to insure that the unit's documented configuration identification (PCI) matches the "as-built" configuration of the hardware. Thiokol will provide PCA planning documents prior to the PCA. Thiokol will have available at the PCA adequate technical documentation for the verification of the "as-built/as-specified" comparison.

In addition to the FCA and PCA, Thiokol will conduct formal design reviews as specified by contract. Thiokol will act as host, provide facilities, specifications, drawings, manufacturing records, and inspection and test records. Formal minutes of each review will be documented by Thiokol for submission to the customer.

7.7 CONFIGURATION ASSURANCE

Thiokol's configuration management system was developed to meet the requirements of AFSCM 375-1. It has been, and will continue to be, modified as required to comply with the philosophy and practices of DOD Directive 5010.19 and DOD Instruction 5010.21. It is anticipated that only minor modifications will be required to satisfy NASA requirements.

Thiokol will provide surveillance and direction in regard to Configuration Management to subcontractors, suppliers, and vendors supplying critical raw materials and components. Standard operating procedures and/or process baselines will be obtained from the subcontractor/vendor supplying the item or material. Upon acceptance by the Configuration Management office and the Thiokol Configuration Control Board, these baselines will be formalized and controlled. Subcontractor/vendor conformance with the approved baseline will be audited by Quality Assurance representatives and the Configuration Management office.

8.0 TOOLING PLAN

8.1 VERIFICATION PROGRAM

This Tooling Plan describes the basic policy, organizational responsibilities, and management controls to be used in the Space Shuttle Solid Rocket Motor (SRM) Stage Special Tooling effort in the verification program.

Hard tooling, that is, tooling which is production oriented and has sufficient durability/design features and interchangeability considerations to be classified as permanent tooling available for use on a repetitive basis, will be employed from the outset. This will insure a minimum of transition problems as the program proceeds from the ED & D phase through the flight program.

All tooling will be tool proofed. That is, it will be verified that tooling will produce component parts which consistently meet all design requirements. Tool proofing includes visual observation and approval of the performance of the tool by representatives of Safety, Process Engineering, Quality Engineering, Manufacturing Engineering, and Works Engineering. In addition, the first article produced during the proofing will be examined and verified for complete acceptability by Quality Assurance personnel.

A review and approval of all special tooling designs by a representative of the Safety Office will be required. This will assure a detailed analysis of the design concept by a trained safety engineer.

Recycle inspection will be used to assure that the tooling continues to produce acceptable parts to drawing tolerances. As a general rule, those tools which control part configuration are recycled. The frequency of the inspection is established by Quality Engineering based on the complexity, usage, and the degree to which the motor would be affected if the tool is deficient. Because of the manrating aspect of this program, maximum use of the recycle inspection concept will be instituted.

It is recognized that special tooling must be properly controlled from initial determination of the need for the tool to the production of the delivery unit to assure economical, on schedule production of acceptable end items. Vendor manufactured tooling will be controlled in a manner which assures compliance with the basic requirements of government regulations and company policy. This control includes provision for review of tool designs to (1) assure that basic quality and safety aspects have been satisfied, and (2) provide for approval of the tool control system to be used by the vendor. Works Engineering will be responsible, under the direction of Manufacturing Engineering, for the total tool control effort. Manufacturing Engineering will initiate the need for a tool. Works Engineering will design, initiate fabrication and tool proof on all tooling, with the advice and concurrence of Safety, Quality Assurance, and Manufacturing Engineering.

THIS SPACE INTENTIONALLY LEFT BLANK

Tooling budgets will be monitored and controlled by the Tool Ledger System. The Tool Ledger will show budget, estimate at completion, and actual costs on each tool, thus giving a visual account of performance on each program. A recent example of tool control performance is the Third Stage Minuteman Qualification Program. The tooling budget was 2.3 million dollars and was accomplished within cost and on schedule. All program objectives were met allowing Thiokol to become a qualified production source for this motor.

8.2 PRODUCTION PROGRAM

The tooling effort in the production program will consist in part of obtaining the additional quantities of tools to meet the production rate. Identical tools will have been tried and proven in the verification program, and changes will be minimal.

All of the concepts described for the verification program will remain the same in production.

Tool sustenance will be a primary tooling function in production. This is the effort required to maintain program tooling in "as new" condition, and also all administrative effort required for configuration control and record keeping necessary to meet applicable government specifications. Tool sustenance is comprised of the following functions.

Recycle inspect certified tools.

Rework defective certified and noncertified tools to print.

Replace worn out or damaged tools.

Modify tools to meet proven changes.

Process documentation for tool rework/modification.

Issue EO's and update drawings.

Control fiscal expenditure for tooling.

Supply materials for tool rework/modification.

Maintain tool record packets.

Refurbish (paint, etc) tooling as necessary.

Continuously monitor acceptability of tooling.

Make spare parts available for tool sustenance.

Supply new tools required for process changes.

The attached tool lists show the tooling requirements for both the verification and production programs.

8.2.1 Case Preparation Special Tooling

Tool Name	DDT & E Quantity	Total Production Quantity
Vertical Stand	1	0
Headend Plug	1	0
Aft End Plug	1	0
Handling Arrangement	1	0
Grit Blast Dolly	1	1
Work Platform	1	1
Degreasing Seal and Wand	1	1
Roller Assembly	1	4
Work Stand - Vertical	1	1
Pneuma-Grip Harness	2	3
Handling Fixture - Skirt Extension	1	1
Insulation Mold Ring (Shims Included)	6	12
Handling Sling	1	1
Chocks	2	10

8.2.2 Insulation Special Tooling

Tool Name	DDT & E Quantity	Total Production Quantity
Cutting Table	1	1
Cutting Dies	1	1
Patterns	1	1
Work Platform - Forward	1	1
Work Platform - Center	1	3
Work Platform - Aft	1	1
Roll Feeding Assembly - Forward	1	1
Roll Feeding Assembly - Center	1	3
Roll Feeding Assembly - Aft	1	1
Skiving Machine	1	4
Rollers	2	8
MEK Applicator	2	8
Insulation Contour Template - Forward	1	1
Insulation Contour Template - Center	1	2
Insulation Contour Template - Aft	1	1

Tool Name	DDT & E Quantity	Total Production Quantity
Vacuum Bag - Forward	1	2
Installation Tool - Vacuum Bag - Forward	1	2
Vacuum Bag - Aft	1	2
installation Tool - Vacuum Bag - Aft	1	2
Vacuum Bag - Center	1	3
Holding Fixture - Magnetic - Center	3	5
Autoclave Dolly	2	3
Handling Fixture Insulation Mold Ring	1	1
Machining Fixture - Joint	1	1

8.2.3 Propellant and Lining Special Tooling

Tool Name	DDT & E Quantity	Total Production Quantity
Handling Harness	1	2
Lifting Beam - Vertical	2	1
Work Stand	1	2
Breakover Trailer	1	1
Rotating Dolly	2	3
Handling Dolly - Harness	1	2
Insulated Conical Container	1	1
Casting Arrangement - Forward	1	1
Casting Arrangement - Center	1	1
Casting Arrangement - Aft	1	1
Casting Base - Center - Aft	1	9
Core - Center	1	9
Core Dolly - Center	1	9
Mold - Aft End	2	12
Centering Ring - Core	2	12
Casting Funnel	1	3
Air Deflector	2	15
Vacuum Bell	1	3
Deaeration Assembly	1	3
Transfer Hopper Assembly	1	3

Tool Name	DDT & E Quantity	Total Production Quantity
Core - Aft	1	3
Casting Sleeve	2	12
Casting Dam	1	3
Skirt Protector	1	3
Headend Alignment Sleeve	1	3
Casting Stand	2	15
Core - Forward	1	3
Casting Stand Adapter - Forward	1	3
Casting Stand Adapter - Aft	1	3
Core Dolly - Forward	1	3
Core Dolly - Aft	1	3
Exhaust Hood	1	1
Lining Pit Stand	3	3
Liner Masking Sleeve	3	3
Liner Cure Seals	3	3
Weighing Tools	1	2
Deaerator	1	2
Sling Assembly	1	1
Core Popping Arrangement	1	1
Work Grating	1	3
Pit Grating	2	15
Overcast Propellant Press	1	1

8.2.4 Igniter Special Tooling

Tool Name	DDT & E Quantity	Total Production Quantity
Vibration Arrangement	1	0
Vibration Fixture	1	0
Firing Arrangement	1	1
Test Stand (0) Component	1	1
Lifting Beam	1	1
Layup Dolly - Horizontal	1	2
Insulation Mold Ring	2	4
Vacuum Bag	1	2
Handling Dolly - Case	5	5
Handling Sling	1	1

Tool Name	DDT & E Quantity	Total Production Quantity
Aft Grain Mold	12	12
Casting Sleeve	12	12
Core Guide	12	12
Core	12	12
Core Retainer	12	12
Casting Adapter	3	3
Casting Piping	1	1
Core Popper	1	1
Handling Container	20	30
Casting Arrangement	1	1

8.2.5 Nozzle Special Tooling

Tool Name	DDT & E Quantity	Total Production Quantity
Handling Fixture Actuator	1	1
Holding Fixture	1	1
Holding Fixture	1	1
Mounting Tool - Magnetic Particle Inspection	1	1
Drill Fixture	1	1
Tank and Rotab Ultrasonic Inspection	1	1
Handling Sling	1	1
Handling Sling Assembly	1	1
Holddown Clamp and Riser Shim	1	1
Holding Fixture	2	2
Drill Fixture	1	1
Work Stand - Mold	1	1
Mold	1	1
Lifting Sling	1	1
Holding Fixture - VTL	1	2
Special Dial Bar Gage	2	2
Vacuum Holding Fixture No. 1	1	1
Vacuum Holding Fixture No. 2	1	1
Vacuum Holding Fixture No. 3	1	1
Vacuum Holding Fixture No. 4	1	1

Tool Name	DDT & E Quantity	Total Production Quantity
Vacuum Holding Fixture No. 5	1	1
Vacuum Holding Fixture No. 6	1	1
Vacuum Holding Fixture No. 7	1	1
Vacuum Holding Fixture No. 8	1	1
Vacuum Holding Fixture No. 9	1	1
Rotating Table	1	1
Work Stand - MEK	1	1
Work Stand - Drying	1	1
Spray Booth Tools	1	1
Work Stand - Layup	1	1
Work Stand - Cutting	1	1
Work Stand - Assembly	1	1
Work Stand - Assembly	1	1
Work Stand - Hand Trim	1	1
Work Stand - Layup	1	1
Work Stand - Bonding	1	1
Flex Joint Mold	1	1
Insulation Blanket	1	1
Lifting Harness	1	1
Cutting Template	1	1
Work Stand	1	1
Work Bench	1	1
Pressure Band	1	1
Pressure Plate	1	1
Shipping Container	1	1
Handling Chock - Rail System	1	1
Vibration Arrangement	1	1
Supports - Ling Shaker	1	1
Slip Plates	1	1
Burst Arrangement	1	1
Burst Test Stand	1	1
Burst Fixtures	1	1
Flexible Bearing Test Fixture	1	1

8.2.6 Final Assembly Special Tooling

Tool Name	DDT & E Quantity	Total Production Quantity
Work Station Jacks	4	8
Work Platform	1	2
Rotating Dolly	8	12
Igniter Cable Bracket Installation Tool	1	1
Pyrogen Lifting Fixture	1	1
Triangular Lifting Beam	1	1

8.2.7 Thrust Termination Special Tooling

Tool Name	DDT & E Quantity	Total Production Quantity
Firing Arrangement	1	1
Test Stand - Single Component	1	1
Forward Core Assembly	1	4
Pad Locating and Bending Tool	1	1
TT Port Mold Removal Tool	1	1

8.2.8 Power Supply Special Tooling

Tool Name	DDT & E Quantity	Total Production Quantity
Checkout Stand	1	1

8.2.9 Ground Test Special Tooling

Tool Name	DDT & E Quantity	Total Production Quantity
Test Stand - 1 Component	1	0
Rounding Harness	3	0
Support Jacks - Segment	1	0
Firing Arrangement	1	0
Optical Alignment Tool	1	0
Lifting Beam	1	0
Rotating Dolly	2	0
Antiflight Device	1	0
APU Attach Bracket	2	0
Δ for 6 Component Stand	1	0
Cradle - Rail System	1	0

9.0 FACILITIES PLAN

9.1 INTRODUCTION

This plan presents the existing facilities, facilities modification, and new facilities requirements for Thiokol to conduct the Design, Development, Test and Evaluation (DDT & E) and Production Programs for the Solid Rocket Motor Stage for the Space Shuttle. This plan is divided into three sections, plant site facilities, operational site facilities, and vendor facilities.

9.2 PLANT SITE FACILITIES

9.2.1 Plant Location and General Description

Thiokol's Wasatch Division was constructed specifically for the development and production of large, solid propellant rocket motors and related hardware. No solid propellant contractor has comparable facilities or experience.

The remote location in Northern Utah, 26 mi west of Brigham City, is ideal for processing and testing production quantities of extremely large motors. The 30 sq mi plant site contains 304 buildings. Most are 10 years old. Figure 9-1 shows the plant location.

The Wasatch Division consists of the Research and Development Plant (R & D Plant), occupying almost 18,000 acres, and the Thiokol-operated Air Force Plant 78 covering 1,515 acres. Combined facilities have produced 156 million lb of solid propellant. Current mixing capacity is 10 million lb a month.

Motor size limitations, without facility modifications, are:

R & D Plant - 200 in. diameter, 38 ft length and 200 tons;
Plant 78 - 100 in. diameter, 22 ft length and 50 tons.

The R & D Plant provides all development and testing capability as well as extensive production capability.

Plant 78 was designed for high rate production of Stage I Minuteman Motors.

9.2.2 Facility Investment Summary

The following summary apportions the $72,998,288 acquisition cost of Wasatch Division facilities by ownership and general category.

THIS SPACE INTENTIONALLY LEFT BLANK

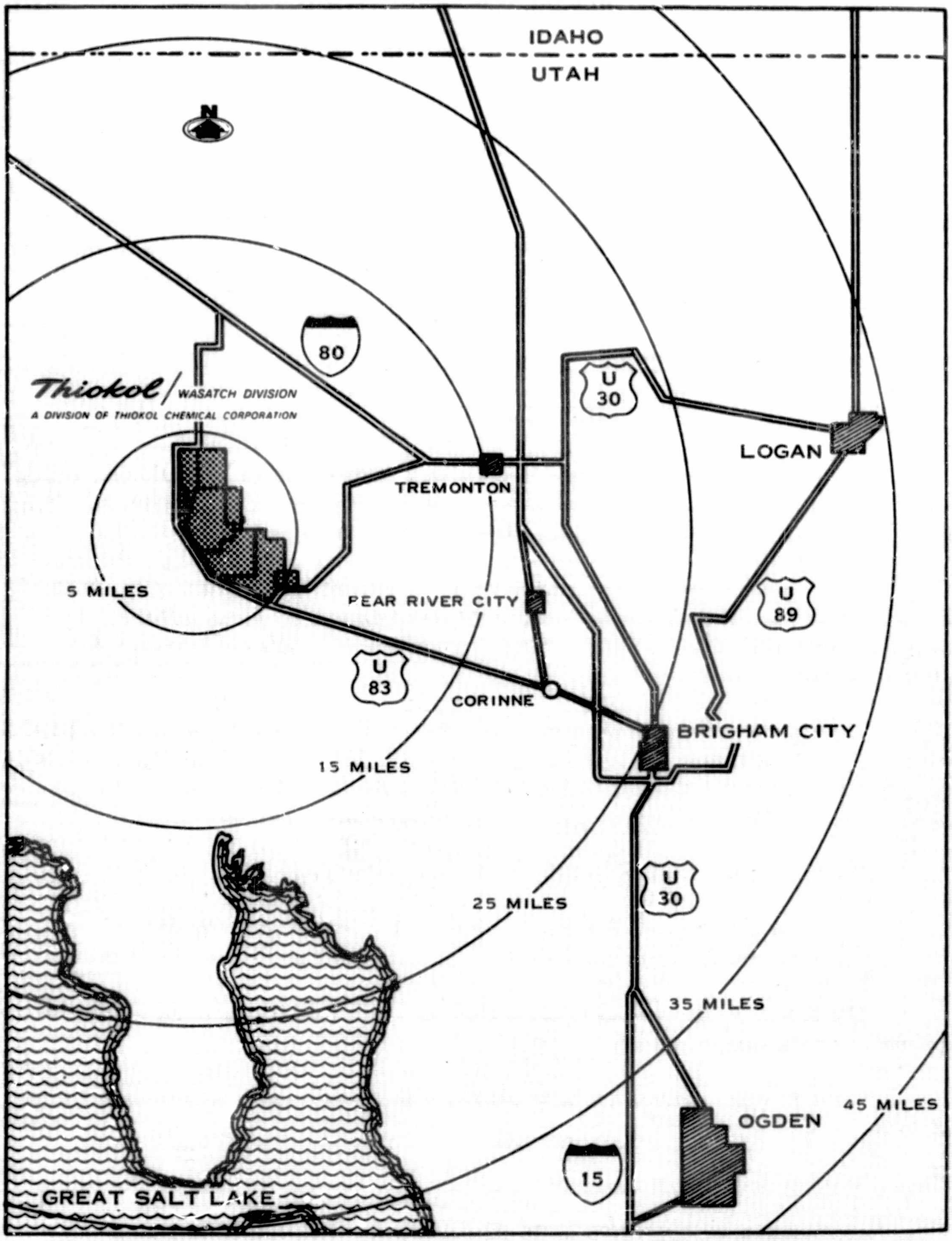


Figure 9-1. Thiokol Plant Location

	Government	Thiokol
Land	$ 9,469	$ 180,511
Buildings and installations	22,122,435	16,155,145
Machines and equipment	18,291,209	13,493,348
Rolling stock	2,349,865	396,306
Total:	$42,772,978	$30,225,310

Government facilities are provided by Contracts AF 04(694)-719 (R & D Plant) and F04694-67-C-0032 (Plant 78) under cognizance of:

Ogden Air Force Plant Representatives Office
Thiokol Chemical Corporation
Wasatch Division
Attn: L. B. Larsen
P. O. Box 524
Brigham City, Utah 84302

9.2.3 Security Clearance, Plant Protection

The Wasatch Division has a secret security rating. Plant areas are fenced. A security guard is maintained 24 hr a day.

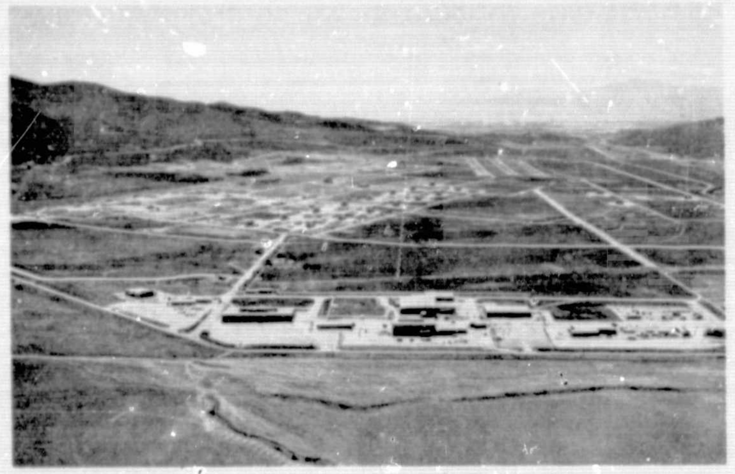
Adequate fire equipment and personnel provide 24 hr coverage.

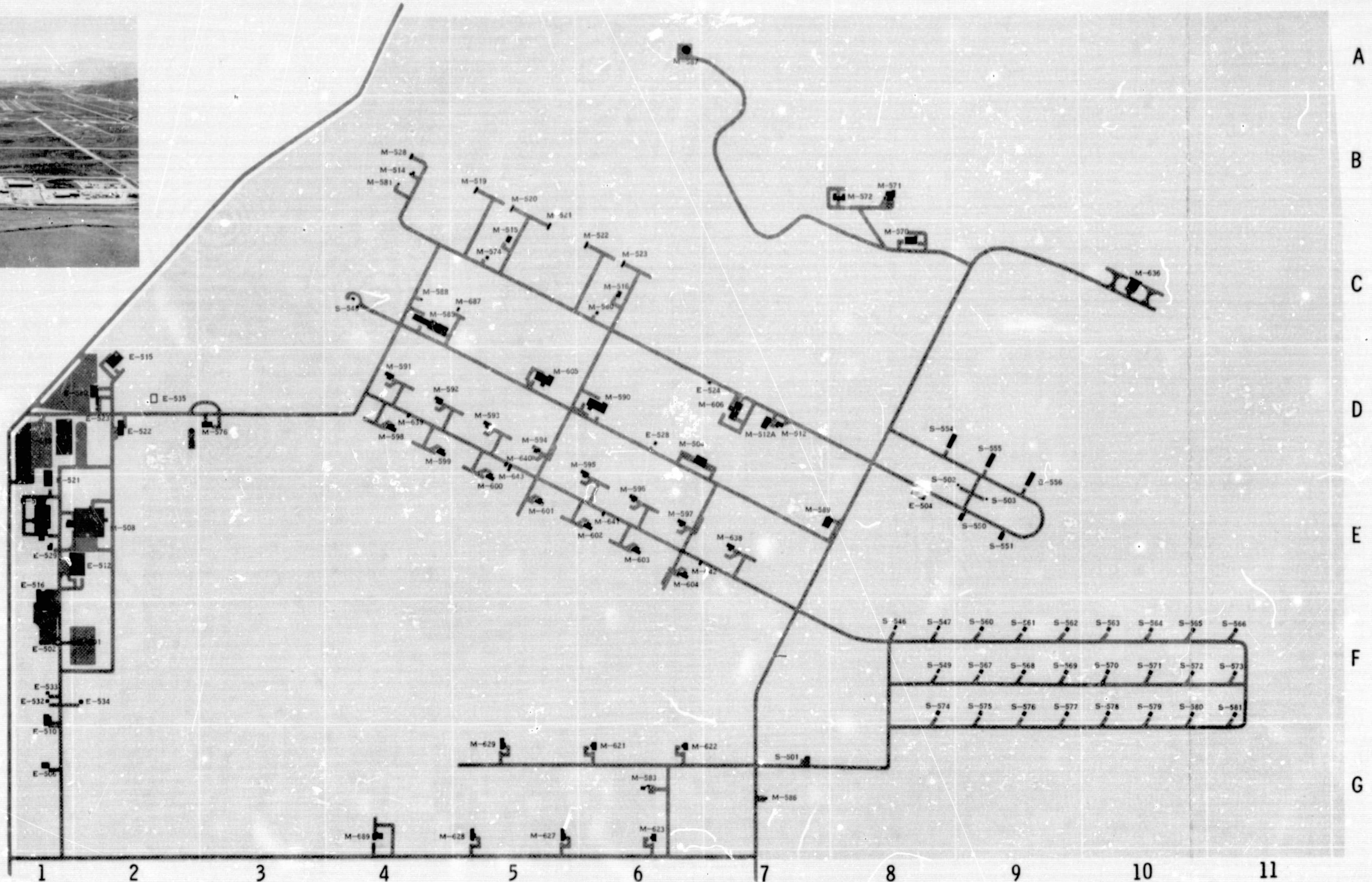
9.2.4. Functional Allocation of Land, Floor Space

Wasatch Division acreage is apportioned to general areas as follows:

R & D Plant:	Manufacturing & Support	10,050
	High Performance Propellant Plant	850
	Test Area	1,150
	For expansion and other	5,730
	Subtotal	17,780
Plant 78:	Manufacturing and Support	1,515
	Total acreage	19,295

Figures 9-2 thru 9-5 identify the major plant areas and the major facilities in each.

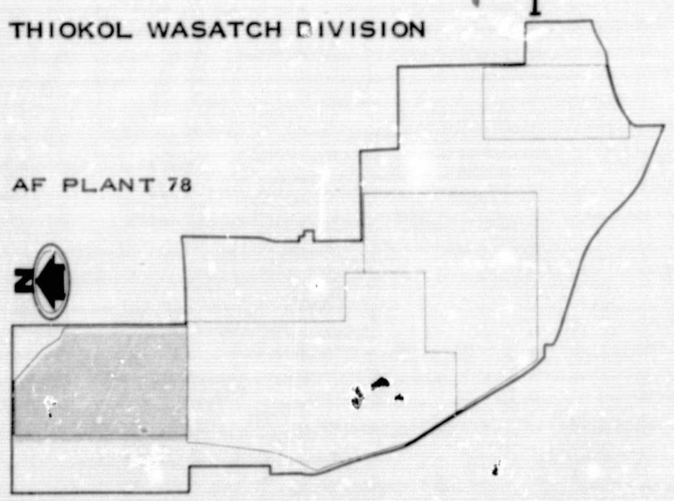




				LOCATION
		ADMINISTRATION		
	•	E-519	ADMINISTRATION	D-1
		INSPECTION		
	•	M-636	RADIOGRAPHIC	C-10
		MFG - ASSEMBLY		
	•	E-529	FLEX SEAL FAB	E-1
	•	M-627	FINAL ASSEMBLY	G-5
	•	M-628	FINAL ASSEMBLY	G-5
	•	M-629	FINAL ASSEMBLY	G-5
	•	M-638	MISCELLANEOUS ASSEMBLY	E-7
	•	M-689	FINAL ASSEMBLY	G-4
		MFG - INERT PARTS		
→	•	E-512	INERT PARTS PREPARATION	E-2
→	•	E-517	MACHINE SHOP	E-1
→	•	M-504	CLEANING	D-6
→	•	M-508	INERT PARTS PREPARATION	E-2
		MFG - MOTOR PROCESS		
	•	M-583	PREFINAL CONTROL	G-6
	•	M-590	SMALL MOTOR MFG	D-6
	•	M-591	CAST-CURE BUILDING	D-4
	•	M-592	CAST-CURE BUILDING	D-4
	•	M-593	CAST-CURE BUILDING	D-5
	•	M-594	CAST-CURE BUILDING	D-5
	•	M-595	CAST-CURE BUILDING	E-6
	•	M-596	CAST-CURE BUILDING	E-6
	•	M-597	CAST-CURE BUILDING	E-6
	•	M-598	CAST-CURE BUILDING	D-4
	•	M-599	CAST-CURE BUILDING	D-4
	•	M-600	CAST-CURE BUILDING	E-5
	•	M-601	CAST-CURE BUILDING	E-5
	•	M-602	CAST-CURE BUILDING	E-6
	•	M-603	CAST-CURE BUILDING	E-6
	•	M-604	CAST-CURE BUILDING	E-6
→	•	M-605	SMALL MOTOR MFG	D-5
	•	M-621	PREFINAL ASSEMBLY	G-6
	•	M-622	PREFINAL ASSEMBLY	G-6
	•	[illegible]	[illegible]INAL ASSEMBLY	G-6
		MFG - PROPELLANT		
	•	M-512, M-512A	PROPELLANT PREMIX	E-2
	•	M-515, M-516	MIXER STAGING	C-5, 6
	•	M-519	HORIZONTAL MIXER	B-5
	•	M-520	HORIZONTAL MIXER	B-5
	•	M-521	HORIZONTAL MIXER	C-5
	•	M-522	HORIZONTAL MIXER	C-6
	•	M-523	HORIZONTAL MIXER	C-6
	•	M-574, M-580	MIXER CONTROL	C-5, 6
→	•	M-606	OXIDIZER GRINDING	D-7
		STORAGE - FLAMMABLE		
	•	M-570	STORAGE	C-8
	•	M-588	SOLVENT STORAGE	C-4
	•	S-501	ORDNANCE PACKING	G-7
	•	S-502, S-503	OXIDIZER	E-9
	•	S-546, S-547, S-549	ORDNANCE	F-8
	•	S-550, S-551	ALUMINUM POWDER	E-9
	•	S-554, S-555, S-556	OXIDIZER	D-9
		STORAGE - INERT		
	•	E-502	MAINTENANCE	F-1
	•	E-504	INERT CHEMICALS	E-8
	•	E-510	WAREHOUSE	F-1
		M-571	ARCHIVES	B-8
	•	M-572	SUPPLIES	B-8
	•	M-589	EQUIPMENT	E-7
		STORAGE - MOTOR		
	•	S-560 THRU S-581	MAGAZINES	F-8, 9, 10, 11
		UTILITIES AND SERVICE		
	•	M-576	BOILERHOUSE	D-3
	•	M-639 THRU M-642	VAC PUMP AND GENERATOR	D-4, 5 E-6
	•	E-516	GARAGE	F-1
	•	E-520	CHANGE HOUSE	D-2
	•	E-521	CAFETERIA	E-1
	•	E-522	FIRE HOUSE	D-2
	•	E-523	GUARD HOUSE	D-2
		LABS - QUALITY		
→	•	E-515	METROLOGY	D-2
	•	M-514, M-528, M-581	STANDARDS MIXER	B-4
→	•	M-585	CHEMICAL ANALYSIS	C-4
	•	M-687	OVEN BUILDING	C-5

THIOKOL WASATCH DIVISION

AF PLANT 78



GRAPHIC SCALE
FEET

• GOVERNMENT BUILDING

→ SELECTED FOR THIS PROGRAM

Figure 9-2. Air Force Plant 78 Site Plan

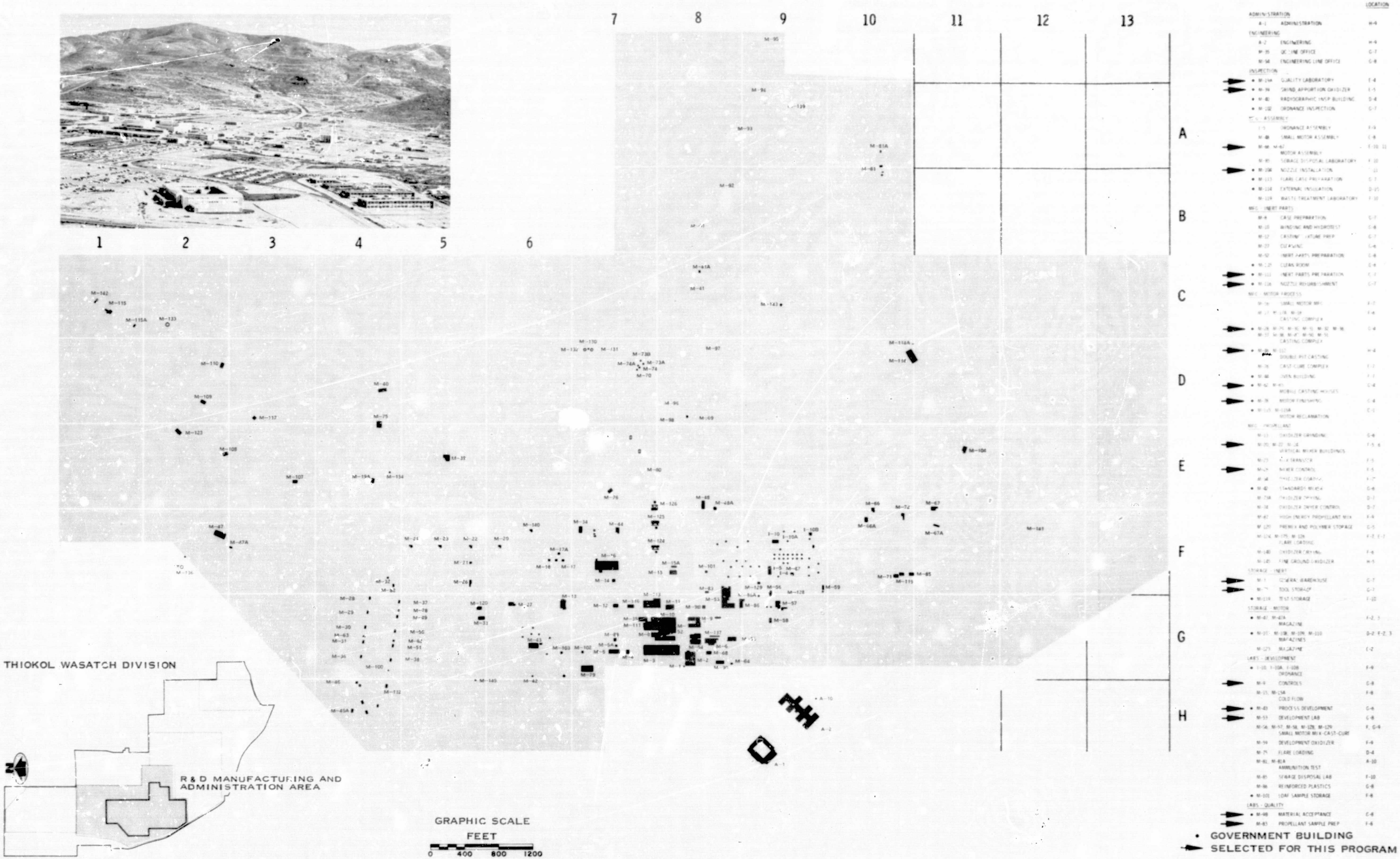
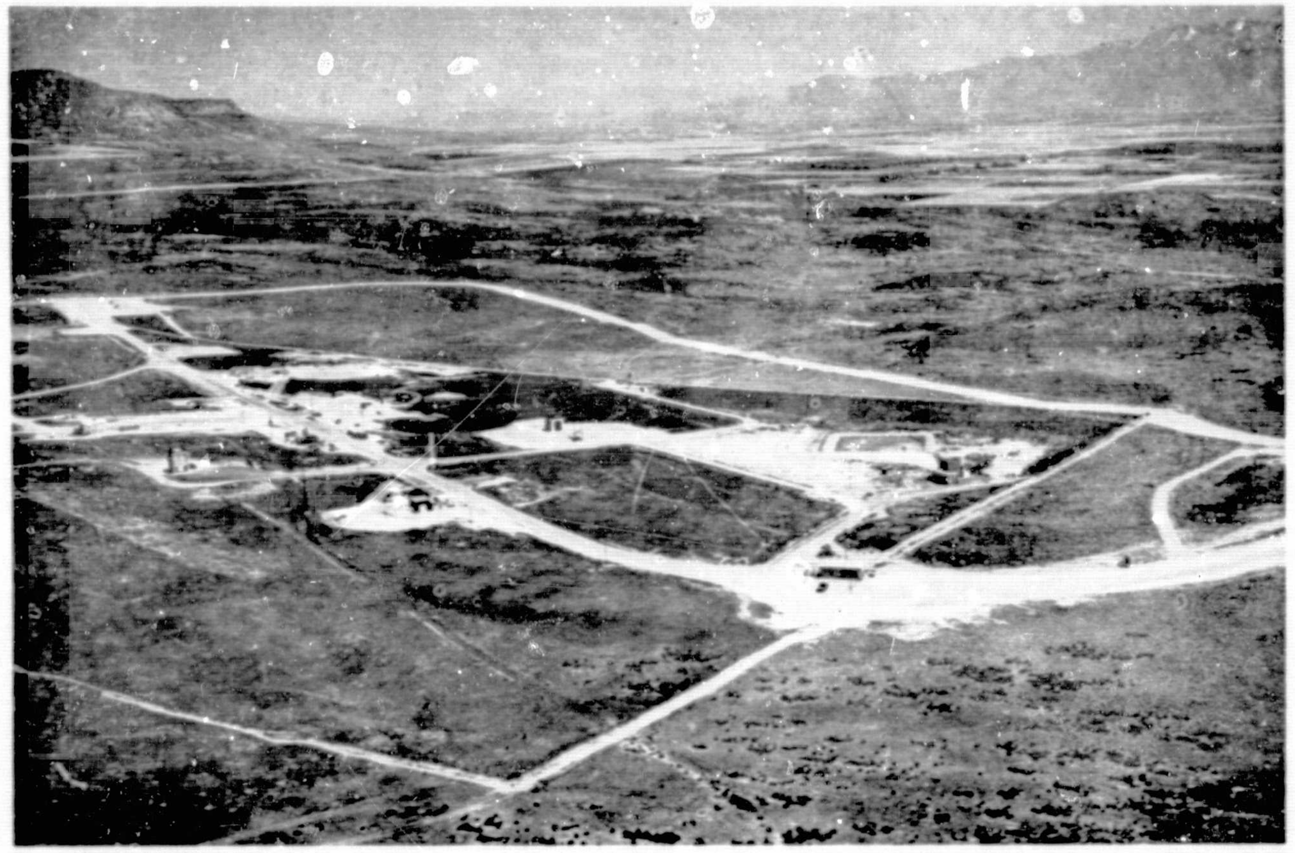
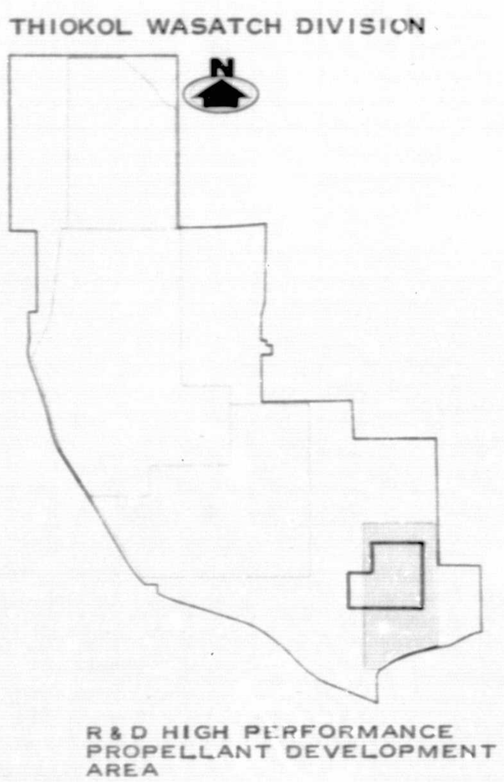


Figure 9-3. R & D Manufacturing and Administration Area Site Plan





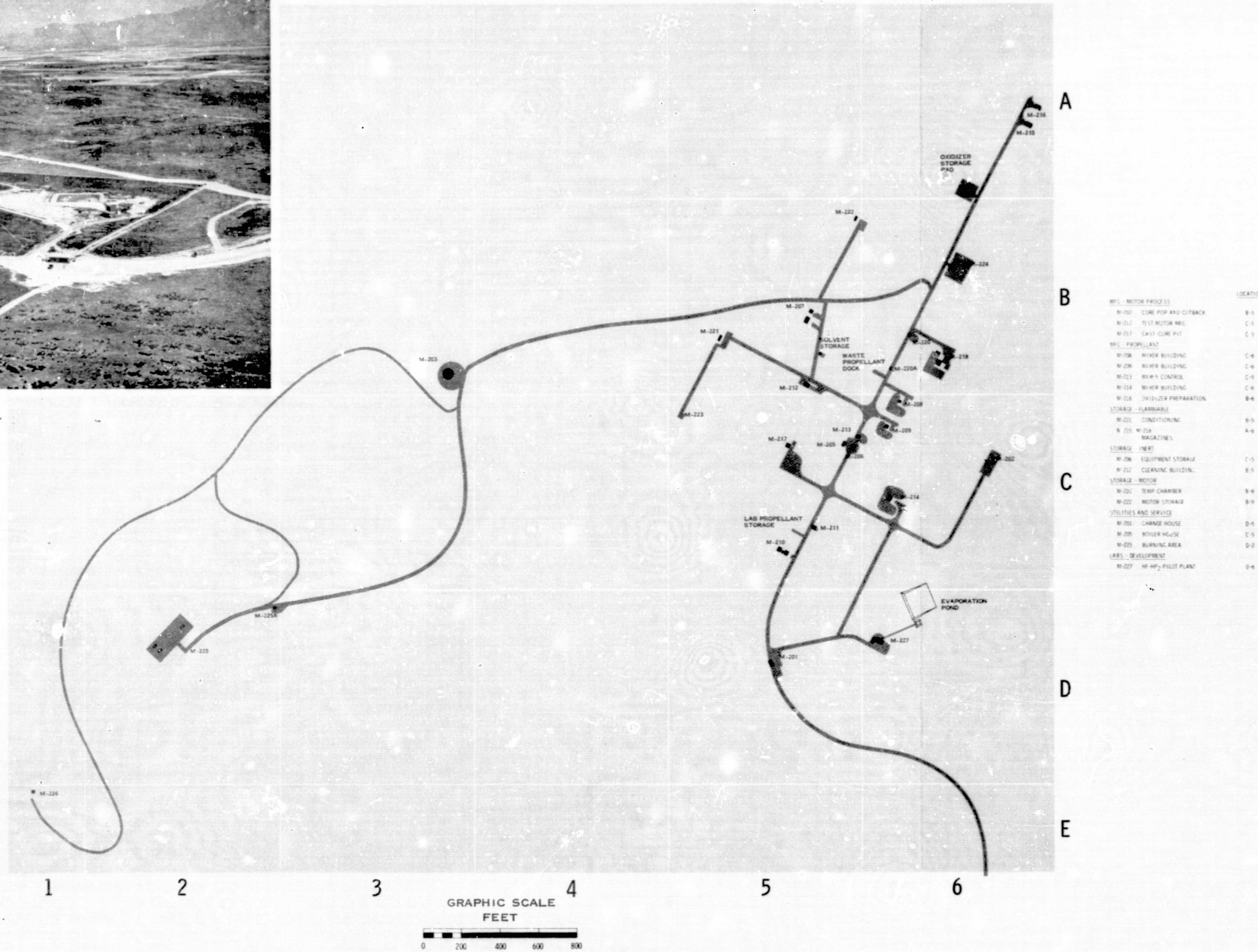
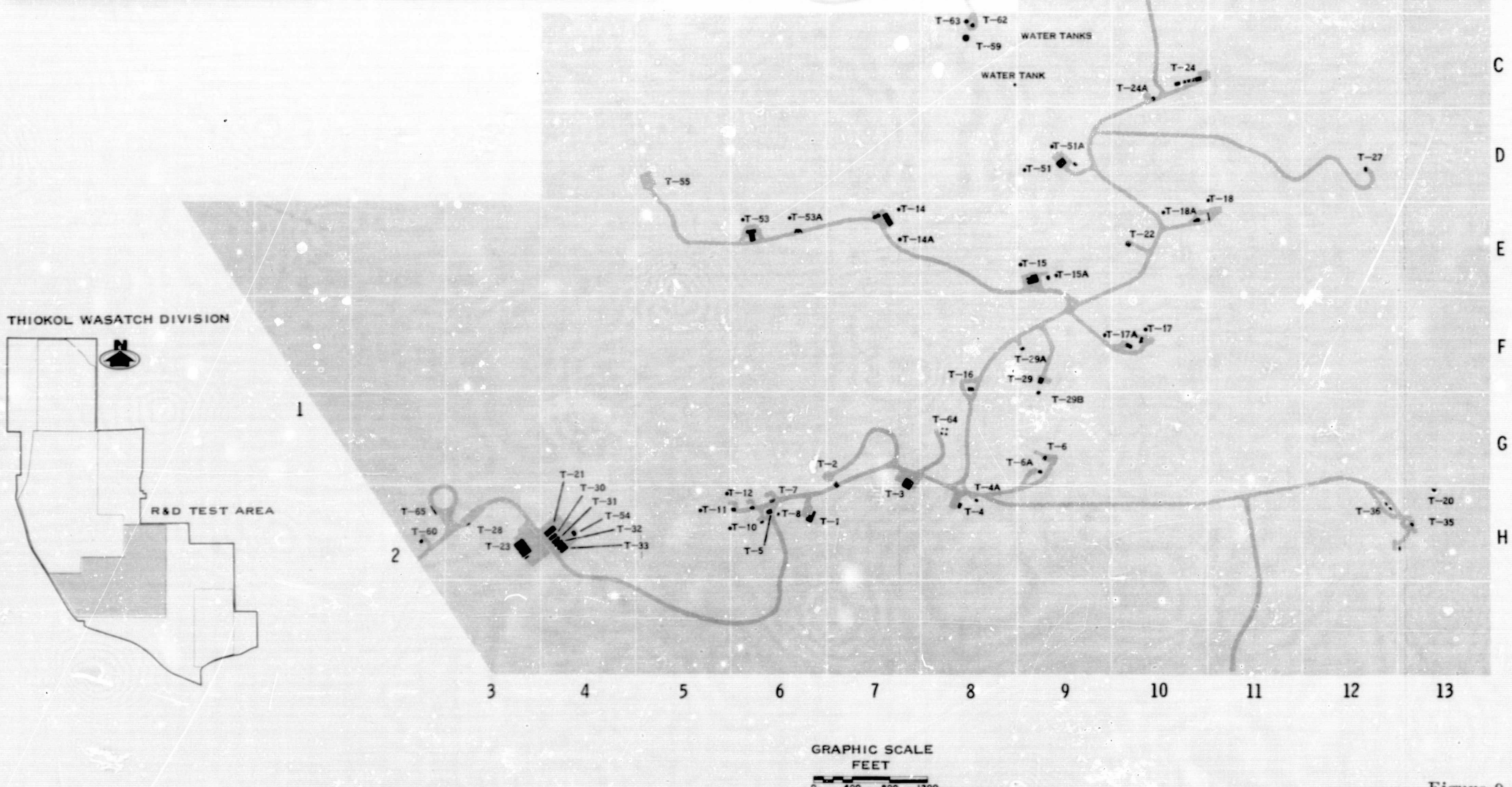


Figure 9-4. High Performance Propellant Area Site Plan



		LOCATION
ADMINISTRATION		
T-1	TEST LINE OFFICE	H-6
T-23	FLARE OFFICE AND SUBASSEMBLY	H-3
MFG - ASSEMBLY		
T-14	TEST INSTRUMENTATION	E-7
T-21	FLARE ASSEMBLY	H-4
UTILITIES AND SERVICE		
T-30	BUTLER BUILDING	H-4
T-33	BUTLER BUILDING	H-4
STORAGE - INERT		
T-5	TEST INSTRUMENT STORAGE	H-6
T-54	FLARE STORAGE	H-4
TEST - ENVIRONMENTAL		
T-3	CONDITIONING	G-7
T-4	DYNAMIC TEST LAB	H-8
• T-15	CONDITIONING	E-9
T-16	VIBRATION	F-8
T-20	DROP TEST	H-13
• T-51	CONDITIONING	D-9
• T-53	VIBRATION	E-6
TEST - STATIC FIRING		
T-2	STATIC TEST BAY	G-7
T-6, T-6A	LARGE MOTOR TEST	G-9
T-7	SMALL MOTOR TEST	H-6
• T-10, T-11, T-12	SMALL MOTOR TEST	H-6
• T-17, T-17A	LARGE MOTOR TEST	F-10
• T-18, T-18A	LARGE MOTOR TEST	E-11
T-22	CONTROL LARGE BAYS	E-10
T-24, T-24A	LARGE MOTOR TEST	C-10
T-35	DESTRUCT PAD	H-13
T-36	CONTROL FOR T-35	H-12

• GOVERNMENT BUILDING
→ SELECTED FOR THIS PROGRAM

Figure 9-5. R & D Test Area Site Plan

Floor space, in totally enclosed buildings only, is:

Administration and Engineering		330,688 sq ft
Inspection		36,992
Manufacturing:	Assembly	82,962
	Inert parts	203,844
	Motor process	140,830
	Propellant mfg	55,976
Storage:	Flammable	29,610
	Inert	102,768
	Motor	41,480
Test:	Environmental	35,836
	Static firing	15,281
Utilities and Support		63,062
Laboratories:	Development	95,875
	Quality	34,995
	Total	1,270,199 sq ft

9.2.5 Transportation, Utilities

Transportation systems are adequate including all airline, truck, and railroad carriers servicing the area and an onsite airstrip. Both plants are located on Utah Highway 83.

Major utilities include 46,000 kv power, water storage of 2.4 million gal supplied by Thiokol-owned wells providing 600 gpm. All utilities are being utilized to a small percentage of capacity and are in good condition.

9.2.6 Summary of Capacity/Utilization

Space Shuttle Verification Program (156 in.):

Operation	Pacing Facility	Facility Capacity At 100% Utilization (seg/mo)	Available Capacity After Other Programs (seg/mo)	Requirements For Shuttle Verification (seg/mo)
Case prep, line	Lining pits	80	80	5
Oxidizer grinding	Mills	27	16	5
Premix	Mixers	40	40	5
Mixing	2 mixers	31	31	5
Casting/curing	4 pits	14	14	5
X-ray	1 Linac	11	11	5
Assembly	--	50	50	5

THIS SPACE INTENTIONALLY LEFT BLANK

Space Shuttle Production Program (156 in.):

Operation	Pacing Facility	Facility Capacity at 100% Utilization (segs/mo)	Available Capacity After Other Programs (segs/mo)	Requirements for Shuttle Production (segs/mo)
Case prep, line	M-111	80	80	50
Oxidizer grinding	M-39, M-606	103	92	50
Premix	Mixers	80	80	50
Mixing	4 mixers	80	80	50
Casting/curing	15 pits	54	54	50
X-ray	4 Linacs	60	60	50
Assembly	M-67, M-104	100	100	50

The capacity shown above is based on provision of the facility additions identified in 9.2.8.

9.2.7 Major Space Shuttle Facilities

9.2.7.1 Case Cleaning, Lining

Building M-111 will be the primary motor case preparation facility. It contains four 15 by 15 by 36 ft lining pits, 17,580 sq ft with 51-1/2 ft ceiling. Present 10 ton hoists will be replaced by 12-1/2 ton units.

Overflow, if necessary, can be accommodated in M-52, a 27,482 sq ft area with a 48 ft ceiling and 20 and 30 ton bridge cranes. A 15 by 32 by 18 ft grit blast chamber, 14 by 14 by 38 ft ovens and a degreasing system adaptable for 156 in. segment processing are available.

9.2.7.2 Propellant Manufacture, Oxidizer Grinding

Wasatch Division capacity in M-606 of 4,140,000 lb/mo will supply the development program. Space Shuttle production will utilize a new facility moved immediately adjacent to the mix/cast complex and providing conveyorized handling. This system will provide 5,520,000 lb/mo. Standby capacity of 4,140,000 lb/mo will be provided by existing systems.

In propellant premixing, a new system is proposed to optimize material handling efficiency. Existing facilities will provide standby capability.

9.2.7.3 Propellant Mixing

Wasatch Division has three 600 gal; three 300 gal; one 150 gal; and two standby, 300 gal mixers. Space Shuttle will use three existing 600 gal mixers automated to

produce 14,000,000 lb/mo. One standby mixer will be provided. Siting is available for additional mixers in the present mixer area.

In production, mixer feeding will be conveyorized for maximum efficiency.

9.2.7.4 Casting

Wasatch existing facilities: 15 cast/cure buildings with 12 by 40 by 32 ft pits and twelve 20 by 20 by 40 ft cast/cure pits with related support equipment. Space Shuttle will use the twelve 20 by 20 pits, rail-mounted gantry cranes, rated to 200 tons, and two casting houses.

Additional pits, gantries, and casting houses will be added as soon as possible.

The three existing linear accelerators, one 8 mev and two 15 mev, are now in buildings which are unsuitable for large segment handling. In production, new buildings will be constructed suitable for two Linacs. Sixty flights a year will require two buildings.

9.2.7.5 Assembly

Wasatch total assembly area is 83,000 sq ft. Space Shuttle is assigned two buildings, each with existing 50 ton bridge cranes. Standby capability exists with 50 ton handling. Doors on final assembly buildings must be enlarged to accommodate the 156 in. segments.

9.2.7.6 Static Test

Wasatch Test Area is 1,150 acres and includes seven static test bays, one with 2-1/2 million lb thrust capacity.

Space Shuttle will utilize the large bay, modified to withstand 3 million lb thrust. A 200 ton gantry exists at the bay.

Conditioning chambers of 12 by 12 by 40 ft are available. However, for the 156 in. configuration, a new chamber will be provided.

Vibration testing capability exists for forces to 400,000 lb and specimens up to 26 by 27 by 69 ft. The existing board course will be required for use on the Space Shuttle Program.

Supporting facilities are adequate including general handling, inspection, and metrology equipment. Engineering support includes an IBM 370 system and peripheral computation systems.

New, loaded-case trailers are required to support the production rates. One 200 ton trailer is available for loaded segments and several 25 to 40 ton trailers for

inert parts handling. Available motor surge magazines are inadequate. A new surge area will be provided.

9.2.8 Additional Facilities Required

Tables 9-1 and 9-2 list all new facility requirements for the Verification and Production programs.

9.3 OPERATIONAL SITE FACILITIES

9.3.1 Introduction

This section describes the facility requirements to transport the SRM segments from Thiokol/Wasatch Division to Kennedy Space Center, Florida; receive, inspect, and store the segments; transport the segments to the final assembly area; and assemble the SRM Stage.

The SRM segments for the Space Shuttle SRM Stage will be manufactured at Thiokol/Wasatch Division located approximately 27 mi west of Brigham City, Utah. After being manufactured, the segments will be transported across state highways to the railroad near Corinne, Utah. At the railroad, the segments will be transferred to railcars for shipment to Kennedy Space Center (KSC), Florida. At KSC, the segments will be removed from the railcar and placed in a receiving, inspection, storage and subassembly (RISS) building until required for SRM Stage buildup. From the RISS building, the segments will be transported by semitrailer to the Vehicle Assembly Building (VAB) from SRM Stage buildup.

9.3.2 New Facilities Required

New facilities will be required at the railhead in Utah, and at the RISS area at KSC. A new roadbed will be required between RISS building and at the VAB at KSC a new rail spur from the existing railroad at KSC to the RISS building.

9.3.2.1 Railhead Facility

A building with approximately 4,000 sq ft of floor space will be required to support the transfer of segments from the semitrailer to the railcar. The building will house the lifting equipment and provide protection during operations that must be performed during inclement weather.

The building will be constructed over a section of the rail track where the railcars can be positioned for transfer of the segments. The floor of the building and apron leading into the building will be reinforced concrete to support the weight of the loaded semitrailer.

A 200 ton crane will be located within the building. The crane will be used in conjunction with a pneumatic lifting device to transfer each segment from the semitrailer to the railcar.

TABLE 9-1

SPACE SHUTTLE
VERIFICATION PROGRAM FACILITIES (DDT & E)

Area	Bldg	Requirement	Quantity	Design Time (hr)	Installation Time (hr)	Purchase	Corporate Funded
Case Prep	M-111	Remove section of partition		20	50	$ 100	
		Relocate existing bench work		100	[illegible]	500	
		Provide benches, stools	10				$ [illegible],000
		Utilities to work stations		100	350	1,000	
		Replace hoist and trolley	[illegible]				10,000
	M-67	Mixer, adhesive					1,590
Lining	M-111	Exhaust system (MEK)					10,000
		Mixer, liner, 75 gal					[illegible]
Propellant	Pits	Gantry crane modification					30,000
		Casting house modification					5,000
		Pump, vacuum, 500 cfm					[illegible],000
		Polywax building					75,000
		Pit covers	2				16,060
		Pads for segment at pit	2				3,000
	M-120	Premix building addition					[illegible]20,000
		Feed, weigh, premix system					[illegible] 000
		Bins, 95 cu ft	10				10,000
	M-39	Apportioning system					100,000
	M-20	Conveyor, mixer feed pilot					14[illegible],000
X-ray	New	X-ray building					437,000
	New	Boiler house					70,000
		Relocate 13 mev Linac		680	1,200	2,000	
		Foundation for jack station		20	400	4,000	
Assembly	M-67	Enlarge doors	2	160	0	15,000	
		Exhaust					[illegible],000
		Utilities to work stations		60	100	200	
		Foundation for jack station		20	400	4,000	
		Painting station					45,000
Handling		Tractor/trailer, 200 ton					270,000
		Pads, case and nozzle storage					[illegible],500
Flex Bearing	M-508	Oven, heat treat					[illegible]00,000
		Tank, ultrasonic					1,500
		Rotator					1,500
		Scale, 100 lb					1,800
		Conveyor, 190 ft					30,000
		Press, compression molding, 8 by 8 ft					145,000
		Cold box, 8 by 8 by 8 ft					6,000
		Exhaust hood					6,000
		Booth, spray					10,000
Quality Control	M-8	Rotary table, 180 in.					200,000
		Surface plate					10,000
		Process control lab equipment					95,000
Test	T-24	Modify bay					[illegible] 000
		Temporary pump installation		350	800	4,000	
		Thrust termination pad		3,500	0	457,600	
		Conditioning chamber					140,000
		Data system, mobile					200,000
		Board course rehabilitation		120	1,000	10,000	
		Pad, hydroburst		200	1,000	2,000	
	T-53	Add instrumentation					50,860
		Cameras	5				20,000
		Totals		5,330	6,100	$500,400	$3,431,860

TABLE 9-2

SPACE SHUTTLE
PRODUCTION PROGRAM FACILITIES
60 FLIGHTS A YEAR

Area	Bldg	Requirement	Quantity	Design Time (hr)	Installation Time (hr)	Purchase	Corporate Funded
Casting	Pits	Pit covers	10				$ 120,000
		Pads at pits	14				21,000
		Modify casting house					70,000
		Motorize casting house					20,000
		New casting house					195,000
		Modify gantry, 50 tons					30,000
		Gantry crane, 200 tons	2				600,000
		Modify gantry, 200 tons					20,000
		Rehabilitate pits	2	1,960	9,000	$ 68,300	
		New pits west of existing	2				268,000
		New pit in new complex					172,200
		Utilities, road					48,500
		Cooling system, mobile	3				60,000
		Pump, vacuum	2				16,000
Mixing		Mix bowls	4				60,000
		Trailers, mix bowl	6				21,000
		Conveyorize mixer feeding	3				450,000
	M-23	Mixer, 600 gal					330,000
		Mixer buildings and mixer, 600 gal	2				1,000,000
		Dump station, replace M-23					70,000
		Addition to mixer control					40,000
Oxidizer	M-39	Modification for grinding					480,000
		Bins, 95 cu ft	2				2,000
Painting		Painting building w/equip.					140,000
		Compressor					5,000
		Foundations, jackstand	2	40	400	4,000	
Quality		Additional QC lab equipment					50,000
Storage		Pad, cases					70,000
		Pad, nozzles					45,000
		Crane, mobile					100,000
		Cold box, 40 by 40 by 14 ft					100,000
		Motor surge area					250,000
		Foundations, motor surge	10	200	2,000	20,000	
Transport		Tractor/trailer, 200 tons					540,000
X-ray		Linear accelerators, 15 mev	3				1,025,000
		Film processors	3				51,000
		X-ray building					430,000
		Foundations, jackstand	3	60	600	6,000	
		Roadway					50,000
		Fencing					10,000
		Warning system					8,500
Assembly		Foundations, jackstand		20	200	2,000	
		Compressor, central					75,000
Utilities/ Services		Addition to boiler house					70,000
		Addition to maintenance shop					110,000
		Office furniture and equipment					300,000
		Addition to change house					75,000
Flex Bearing		Lathe, VTL	3				600,000
		Totals		2,280	12,200	$100,300	$8,198,200

Figure 9-6 shows a conceptual drawing of the required facility at the railhead in Utah. The total estimated cost of this facility including the crane is $210,000, NASA funded.

9.3.2.2 RISS Building

Upon arrival at KSC, the segments will be transferred to the RISS building for receiving, inspection and storage. The RISS building will be a multipurpose building with approximately 30,000 sq ft of floor space.

Each segment will be brought into the building and transferred from the railcar to storage chocks. The floor of the building will be reinforced concrete to support the semitrailer during transfer and to support the segments during storage. Sufficient space will be required to perform receiving and inspection functions and store up to 15 segments as well as other components such as the attach structure, nose fairing, and miscellaneous components.

Space will be required to receive, inspect, and store miscellaneous components such as the nose fairing, attach structure, segment attach hardware, raceway covers, miscellaneous black boxes, etc. Rack and shelves should be provided for this storage.

The RISS building will house the offices and support areas required in the administration of the SRM operations. Support areas would include document storage, tool storage, reproduction area, restrooms, etc.

The entire segment storage area must be serviced by an overhead crane with a 200 ton capacity. The crane will be used while transferring the segments from the railcars to storage chocks and then to the semitrailer.

Auxiliary hoists to 10 ton capacity will be required to service the receive and storage areas of the miscellaneous components.

Figure 9-7 shows a conceptual drawing of the required RISS facility at KSC. The estimated cost for this facility, including the 200 ton gantry crane, is $1,500,000, NASA funded.

9.3.2.3 Roadway

A new roadway will be required between the RISS building and the VAB. This roadway must have sufficient capacity to support the loaded semitrailer. The estimated cost for this roadway is $25,000, NASA funded.

9.3.2.4 Railway

The segments will be brought onto the KSC from the railhead at Titusville, Florida. A new spur will be required from existing trackage to the new RISS building.

This spur will have sufficient capacity to support a train with a minimum of five segments loaded on flatcars. The estimated cost for this rail spur is $40,000, NASA funded.

9.3.3 Existing Facilities

SRM Stage buildup will be performed in the existing VAB on one of the mobile launcher platforms. Existing cranes in the VAB have sufficient capacity to lift the segments and components. The work platform in the VAB probably will have to be modified to provide work space at the appropriate levels on the SRM's.

9.4 VENDOR FACILITIES

Vendor facilities requirements have been identified for both the DDT & E program and the production program.

During DDT & E, facilities will be required by the vendors for case forging and case machining and the vendor for nozzle fabrication. The estimated facilities costs are $2,994,200.

During production, additional facilities will be required by the above vendors, and in addition, a major facility expansion will be required by the ammonium perchlorate vendor. The total estimated cost for these facilities is $101,603,000.

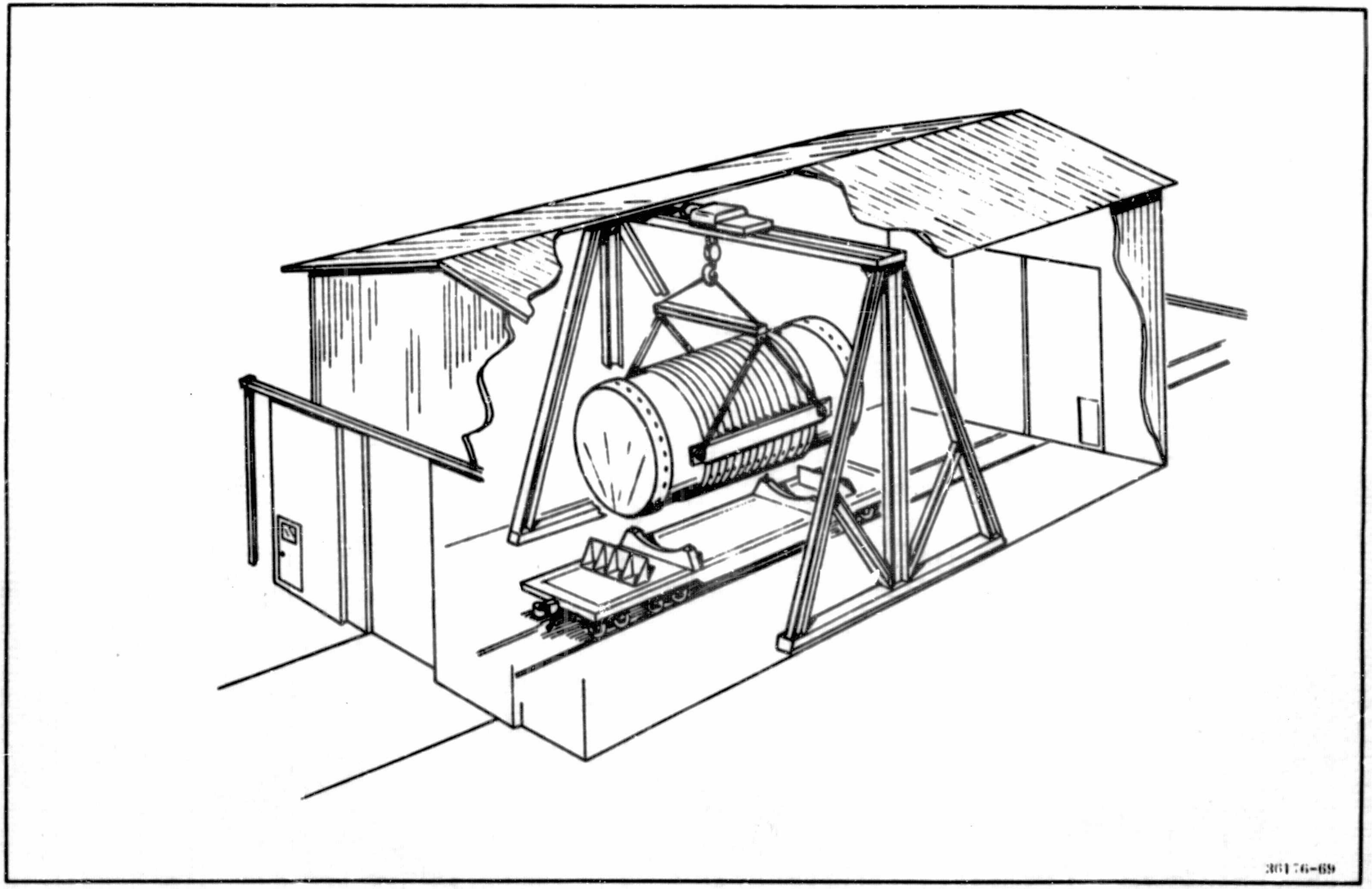


Figure 9-6. Railhead Facility

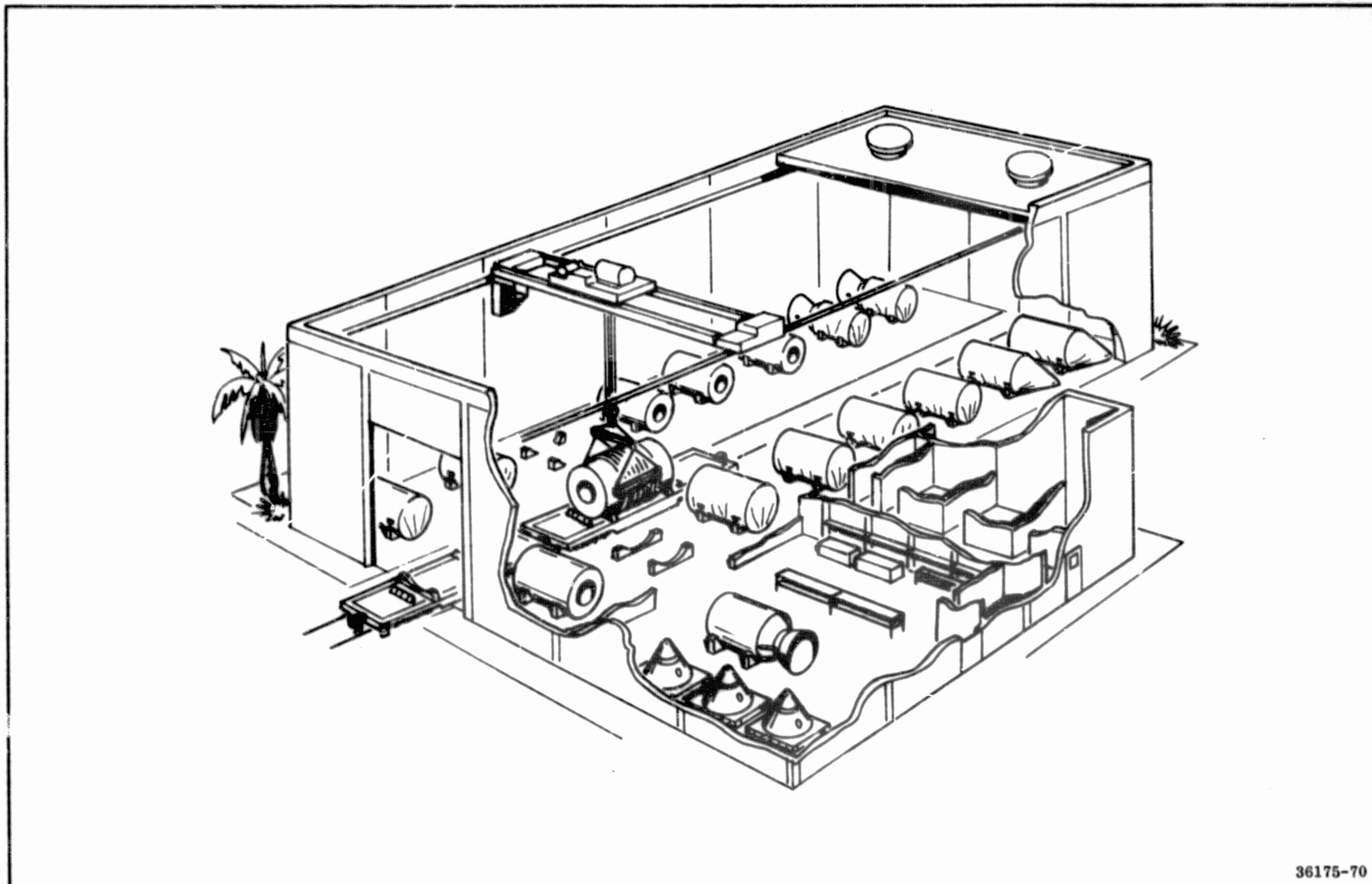


Figure 9-7. Receiving, Inspection, Storage, Subassembly (RISS) Facility

10.0 MASS PROPERTIES CONTROL PLAN

10.1 INTRODUCTION

This Mass Properties Control Plan for the Solid Rocket Motor (SRM) Stage of the Space Shuttle Program specifies the tasks to be accomplished and establishes the system that will be used by Thiokol for mass properties control, determination, and verification. This plan also provides for the preparation and submission of mass properties reports to comply with the mass properties requirements and objectives of the Space Shuttle Program. This Control Plan complies with the requirements of MIL-M-38310A, Mass Properties Control Requirements for Missile and Space Vehicles.

Thiokol will establish and maintain a mass properties control system to assure the following.

1. Compliance with the requirements established by the procuring activity to insure mission mass properties objectives are achieved.

2. That mass properties limits, when established, are achieved.

3. Compliance with the Data Procurement Document (DPD) requirements of the contract.

4. Determination and reversal of adverse trends in mass properties characteristics.

5. That the required data are reported accurately and on time.

Thiokol will develop supporting plans for the system of mass properties control to insure the effective execution of control functions including, as a minimum, a verification plan, and an operational field support plan.

10.2 ORGANIZATION

The responsibility for the implementation of this plan rests with the Project Engineering organization under the cognizance and direction of the Program Manager. Project Engineering will direct, coordinate, and integrate to assure the correct and timely completion of the requirements of this program. Mass Properties Analysis will be accomplished at the component and subsystem level by the Mass Properties Control Engineer under Project Engineering direction. The organization relationships are shown in Figure 10-1 and the data flow process is shown in Figure 10-2.

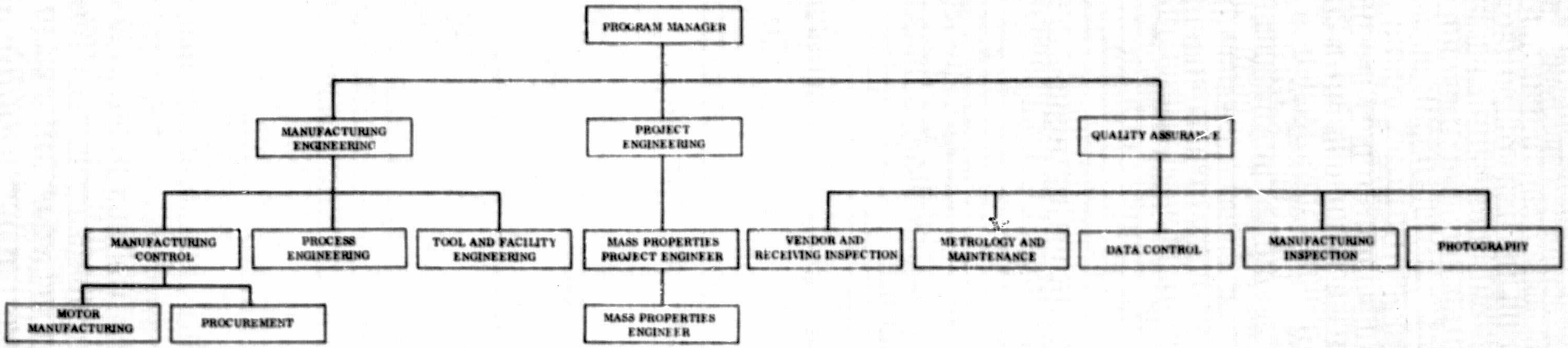


Figure 10-1. Solid Space Shuttle Booster Mass Properties Organizational Assignments

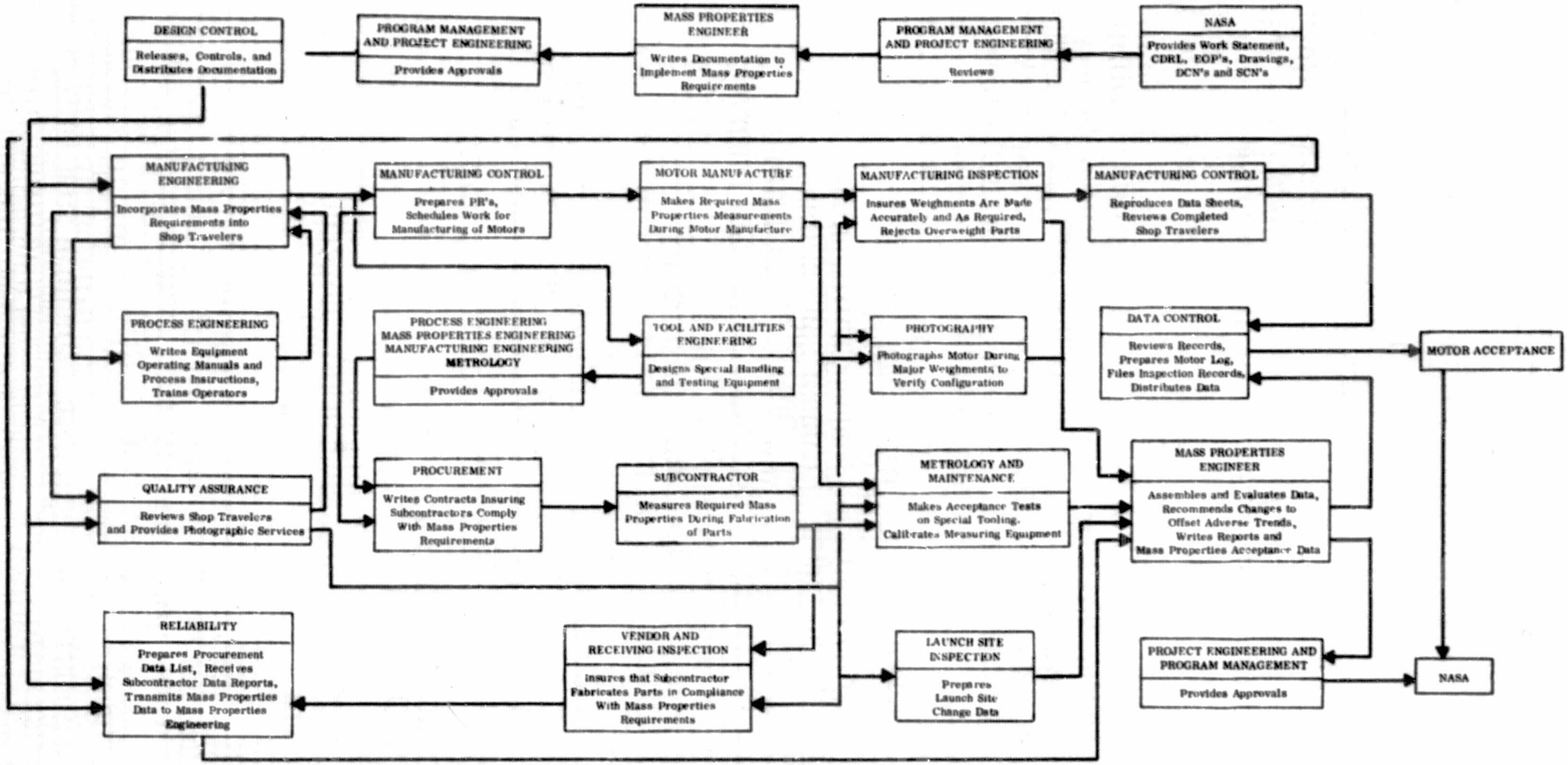


Figure 10-2. Mass Properties Data Flow Chart

10.3 TECHNICAL

10.3.1 Establishment of Mass Properties Base for Control and Reporting

Component mass properties will be determined from detail drawings. These data will be compiled and submitted in the first detail mass properties report within 30 days after contract go-ahead. This report, after approval by NASA, will establish the baseline for control and reporting of mass properties data.

10.3.2 Mass Properties Control

Thiokol engineers specially trained in weight control will be assigned to monitor design activities. It is their established duty to influence the design so that the released drawing weight will be equal to or less than the base weight established. During fabrication of parts and assemblies in the factory, monitoring will be provided to assure, for example, the proper use of attachments and potting compounds, accurate routing of circuitry and plumbing, etc. The receiving-inspection facility personnel will check the weight of incoming items as a part of their standard procedure. In-tolerance weight will be a criterion for acceptance of the part.

An integral part of control through design monitoring is the authority vested in the engineer performing the function. All drawings, engineering change orders, specifications, and other documents will be reviewed, and those affecting mass properties will be approved by the responsible mass properties engineer before they are released; or if released without approval, this shall be so noted. Following current standard procedure, detail weights will be calculated and recorded in the unit weight column of the list of materials on every drawing produced by Thiokol.

Thiokol will establish and maintain a summary of potential design improvements which could be used to offset mass properties or performance degradations. This summary will be updated monthly and reported in the mass properties status reports for review and final action by NASA.

The uncertainty for each of the critical mass properties will be established by Thiokol using analytical methods. These established uncertainties will be used in dispersion studies, for analytical verification of computed nominal values, and in the identification of system elements which warrant verification by experimental methods.

Thiokol will provide and maintain, in a form available for review by the procuring activity, an account which identifies the nature, magnitude, and sequence of each change in proposed mass properties from the initiation to the termination of the program.

The mass properties center-of-gravity data will be based on the coordinate system shown on Figure 10-3.

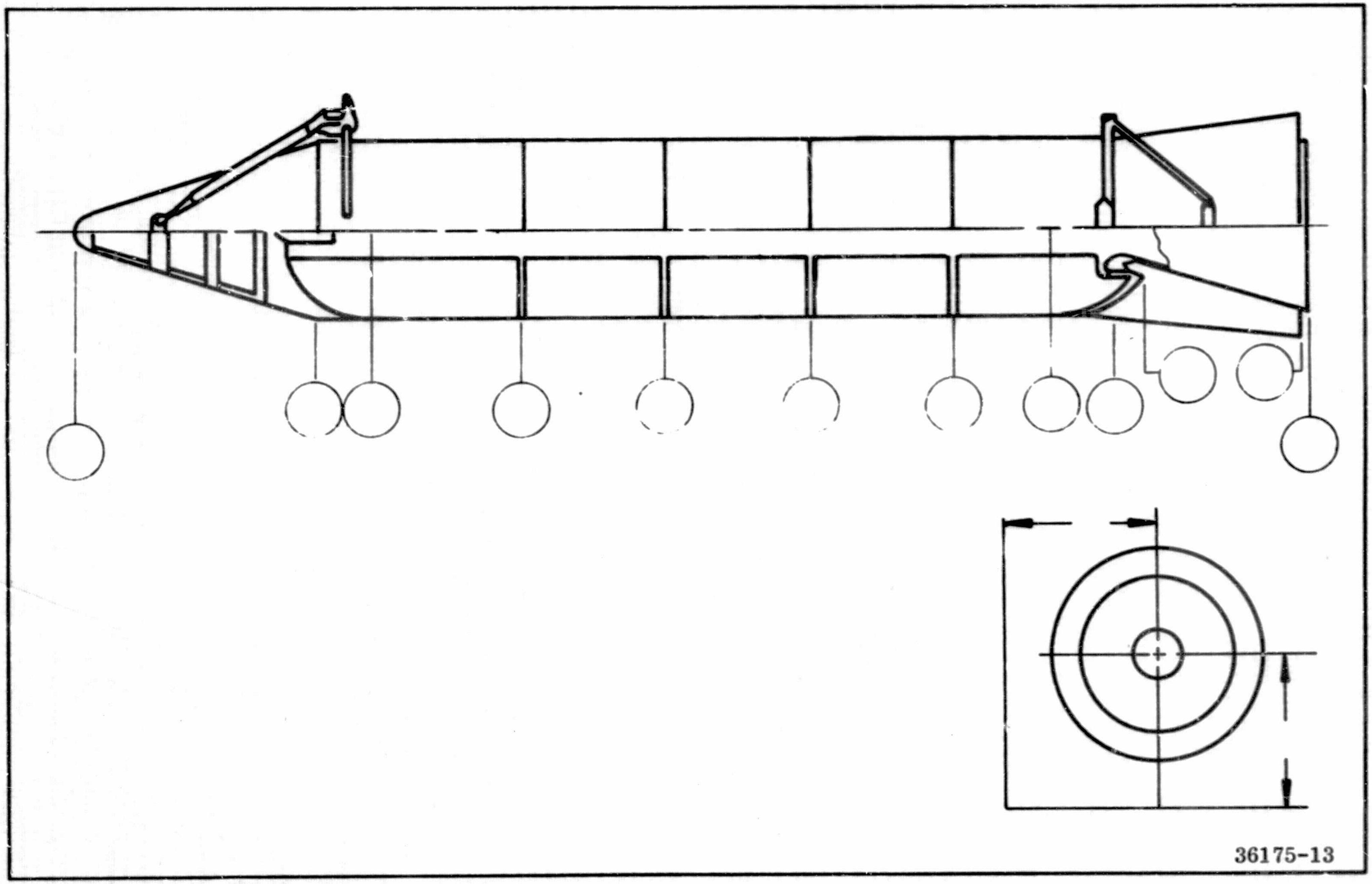


Figure 10-3. Center of Gravity Reference Diagram

Thiokol will perform analyses to assist NASA in the establishment and maintenance of contractual mass properties limits. The analyses will support and establish the allowable limiting values based upon mandatory and acceptable system objectives and functions under the current design.

10.3.3 Vendor Mass Properties Control

An appropriate mass properties section, comparable to and compatible with the contractual requirements, will be incorporated into each procurement document negotiated with a subcontractor who is supplying properties significantly affecting the system mass properties.

Subcontractors with design responsibility will be required to submit mass properties reports to Thiokol in accordance with Table 10-1. These reports will be used to insure subcontractor compliance with mass properties requirements and as inputs to mass properties reports submitted by Thiokol to the customer. Vendors also will be required to comply with paragraphs 10.3.3.1.1, 2, and 3.

10.3.3.1 Subcontractors Fabricating Thiokol Designed Parts

Subcontractors fabricating components to Thiokol design disclosures will be required to comply with the following requirements.

10.3.3.1.1 Compliance with Maximum Requirements

All subcontractors manufacturing and supplying Thiokol parts, components, or assemblies with maximum weight requirements specified on the drawing or in the specification describing the part will be required to comply with these requirements. Each procurement specification will include a statement requiring the subcontractor to submit a calibration system plan showing compliance with Specification MIL-C-45662A for all scales used to verify compliance with the maximum weight requirement. Compliance with all maximum weight requirements will require verification by mass measurement that each item shipped to Thiokol is less than or equal to the maximum specified weight. Compliance requires the use of scales that are graduated in increments of small enough size, and calibrated to a close enough accuracy, to insure that the measured weight of any part, component, or assembly will be at least one-half dial division or the specified scale accuracy (whichever is larger) below the required maximum weight.

10.3.3.1.2 Mass Measurement Requirements

All components, parts, or assemblies which are not required to comply with a drawing or specification specified maximum weight, but which are (1) considered part of the motor inert mass, (2) manufactured by a subcontractor, and (3) expected to weigh ten pounds or more shall be weighed by receiving inspection personnel.

TABLE 10-1

SUBCONTRACTOR MASS PROPERTIES REPORT

Report Element	Schedule of Submittals
Title Page	X
Table of Contents	X
Introduction	X
Contractor Mass Properties Organization	+
Mass Properties Summary	X
Detail Mass Properties	
Mass Properties Change Analysis	X
Trade Data	+
Pending Mass Properties Change Analysis	X
Summary of Improvement Potentials	X
Unresolved Problems	X
Mass Properties History Log	
Sequenced Mass Properties Data	X
Powered Flight Mass Properties	
Diagrams	X
Mass Properties Substantiating Data	
Government Furnished Equipment	+
Computer Cards or Tapes	(X)
Mass Distribution	
Mass Properties Dependent Design Information	+
Structural Increments for Design Features	
Records for All Measurements	
Records for Dry Mass Properties Measurements	
Records for Fluid Mass Properties Measurements	
Summary of Critical Mass Properties	X
Evaluation of Flight	
Critical Mass Properties Uncertainties	+
Mass Properties Limits	+
Parameters and Inventory of Fluids and Propellants Loaded	
Capacity and Loading Information for Fluids and Propellants	

TABLE 10-1 (Cont)

SUBCONTRACTOR MASS PROPERTIES REPORT

Report Element	Schedule of Submittals
Mass Properties Verification Plan	+
Operational Support Plan for R & D	
Operational Support Plan for Orbital Phase	
Proposed Statement of Work	
Operational Support Plan for Targeting	
Operational Targeting Data	
Program Plan	

Notes: + update only - submit changes to the data information or analyses contained in the last published report of these items

(X) submitted as required by procuring activity

X design - first of each month after approved definitive contract (or go-ahead) and ending with delivery of last item.

When fifteen or more such parts have been weighed, the mean weight and the standard deviation about the mean will be calculated and compared with the weight envelope requirements established above. If the values are within the envelope, the weighments will be discontinued until a design change occurs. If the values fall outside the envelope, a maximum weight for the item will be established and subcontractor required to comply with 10.3.3.1.1 above.

10.3.3.1.3 Records

All mass and balance data shall be recorded by part number and serial number.

10.3.4 Mass Properties Accounting and Computing System

The mass properties accounting system, utilizing high speed digital computers, will systematically record and store the information necessary for determining and evaluating the Space Shuttle Solid Rocket Motor Stage weight, center-of-gravity, and moments of inertia.

A solid rocket motor detail parts list that includes drawing number, part identification, next assembly, and end item designation will be used by mass properties engineers to insure that the mass properties of each detail component has been determined. Mass properties data for the various end items, ie, forward closure assembly, aft closure assembly, segment assembly, Thrust Vector Control (TVC) assembly, etc, will be stored in such a manner that if a change is required, new end item data can be substituted in a minimum amount of time. Coordination will be maintained with field personnel so that complete current information will be available constantly.

Mass properties calculations will be performed through the use of high speed digital computers. The computer programs are based on the calculus definition of volumes, moments, and moments of inertia with the necessary integrations being performed by the computer. Output data, consisting of weight, three axis center-of-gravity and three axis moment of inertia are generated in such a manner that reproduction directly from output sheets is possible. An example of the printout is shown in Table 10-2. Mass properties data as a function of time also are generated utilizing the computer. Grain configurations at various times during motor operation are geometrically defined, based on thrust versus time and accounting for the effect of erosive burning. Inert mass properties data versus time, based on temperature, time exposed, material properties, and location in the motor, are generated and input to the computer. Output data, consisting of weight, three axis center-of-gravity and three axis moment of inertia as a function of time are generated in such a manner that reproduction directly from output sheets is possible. A sample of the format can be found in Table 10-3.

TABLE 10-2. DETAIL MASS PROPERTIES SUMMARY SAMPLE FORMAT

BASELINE SOLID ROCKET MOTOR SPACE SHUTTLE 156 IN BOOSTER-PARALLEL BURN

	WEIGHT (LBS)	CENTER OF GRAVITY LONG.	LAT.	VERT.	MOMENT OF INERTIA PITCH	ROLL	YAW
CASE ASSEMBLY	102754.980	918.487	200.000	200.000	2951.267	130.792	2951.267
FORWARD SEGMENT	14395.715	382.327	200.000	200.000	16.934	17.215	16.934
FORWARD CLOSURE	5827.543	329.384	200.000	200.000	3.649	6.033	3.649
IGNITER BOSS	50.879	282.480	200.000	200.000	0.000	0.001	0.000
FORWARD SKIRT	2017.368	339.235	200.000	200.000	1.410	2.644	1.410
BASIC SHELL	3759.296	324.732	200.000	200.000	2.155	3.388	2.155
CYLINDER	8568.172	418.336	200.000	200.000	7.361	11.183	7.361
BASIC SHELL	8031.024	415.095	200.000	200.000	6.723	10.489	6.723
ATTACH FLANGE-FEMALE	537.148	466.797	200.000	200.000	0.347	0.694	0.347
CENTER SEGMENT NO. 1	22943.254	609.375	200.000	200.000	49.373	29.955	49.373
ATTACH FLANGE-MALE	64.637	469.449	200.000	200.000	0.041	0.083	0.041
BASIC SHELL	22341.469	606.440	200.000	200.000	46.433	29.179	46.433
ATTACH FLANGE-FEMALE	537.148	748.297	200.000	200.000	0.347	0.694	0.347
CENTER SEGMENT NO. 2	22943.254	890.875	200.000	200.000	49.373	29.955	49.373
ATTACH FLANGE-MALE	64.637	750.949	200.000	200.000	0.041	0.083	0.041
BASIC SHELL	22341.469	887.940	200.000	200.000	46.433	29.179	46.433
ATTACH FLANGE-FEMALE	537.148	1029.797	200.000	200.000	0.347	0.694	0.347
CENTER SEGMENT NO. 3	22943.254	1172.375	200.000	200.000	49.373	29.955	49.373
ATTACH FLANGE-MALE	64.637	1032.449	200.000	200.000	0.041	0.083	0.041
BASIC SHELL	22341.469	1169.440	200.000	200.000	46.433	29.179	46.433
ATTACH FLANGE-FEMALE	537.148	1311.297	200.000	200.000	0.347	0.694	0.347
AFT SEGMENT	18950.505	1425.965	200.000	200.000	29.052	22.953	29.052
CYLINDER	12744.432	1389.686	200.000	200.000	14.223	16.643	14.223
ATTACH FLANGE-MALE	64.637	1313.949	200.000	200.000	0.041	0.083	0.041
BASIC SHELL	12679.795	1390.072	200.000	200.000	14.101	16.560	14.101
AFT CLOSURE	6206.072	1500.465	200.000	200.000	3.774	6.310	3.774
BASIC SHELL	3110.185	1456.589	200.000	200.000	1.781	3.042	1.781
AFT SKIRT	2113.739	1490.292	200.000	200.000	1.436	2.765	1.436
NOZZLE BOSS	982.148	1534.634	200.000	200.000	0.252	0.503	0.252
SEGMENT ATTACH PROVISIONS	579.000	921.929	200.000	200.000	14.409	0.758	14.409
PINS	307.200	889.350	200.000	200.000	6.770	0.404	6.770
RETAINERS	82.800	889.350	200.000	200.000	1.825	0.109	1.825
BOLTS	34.000	889.350	200.000	200.000	0.749	0.045	0.749
SEALANT	155.000	1011.050	200.000	200.000	4.702	0.200	4.702

MOMENT OF INERTIA IS IN SLUG FEET SQUARED DIVIDED BY 1000 ABOUT AXES THRU THE CENTER OF GRAVITY

TABLE 10-3. SEQUENTIAL MASS PROPERTIES DATA SAMPLE FORMAT

BASELINE SOLID ROCKET MOTOR SPACE SHUTTLE 156 IN BOOSTER-PARALLEL BURN

	WEIGHT (LBS)	CENTER OF GRAVITY LONG.	LAT.	VERT.	MOMENT OF INERTIA PITCH	ROLL	YAW
LAUNCH TIME 0.00	1371744.854	917.536	200.273	200.046	38553.706	1055.334	38551.094
BEGIN ACTION TIME TIME = 3.00	1343271.996	918.657	200.279	200.046	37710.543	1043.589	37707.931
10 PERCENT TIME = 13.42	1246382.606	922.957	200.300	200.050	34799.927	1003.587	34797.313
20 PERCENT TIME = 26.84	1115974.479	928.900	200.336	200.056	30918.134	943.825	30915.517
30 PERCENT TIME = 40.26	985073.030	933.897	200.380	200.063	27163.359	877.719	27160.739
40 PERCENT TIME = 53.68	854314.116	938.100	200.438	200.073	23534.930	803.722	23532.305
50 PERCENT TIME = 67.10	724800.541	941.443	200.517	200.086	20063.679	720.812	20061.048
60 PERCENT TIME = 80.51	597716.784	943.741	200.627	200.105	16780.959	628.420	16778.320
70 PERCENT TIME = 93.93	474068.236	944.406	200.790	200.132	13712.709	526.046	13710.057
80 PERCENT TIME = 107.35	354974.226	941.986	201.056	200.176	10881.106	413.741	10878.433
90 PERCENT TIME = 120.77	241932.028	932.926	201.551	200.259	8345.499	292.360	8342.786
END OF ACTION TIME TIME 134.80	146780.877	941.327	202.551	200.425	6645.357	177.245	6642.566

MOMENT OF INERTIA IS IN SLUG FEET SQUARED DIVIDED BY 1000 ABOUT AXES
THRU THE CENTER OF GRAVITY

10.3.5 Mass Properties Verification

Each critical mass property shall be verified by Thiokol. The method of verification will be presented in the verification plan and used only after approval of the procuring activity.

Contract end item mass properties will be verified by Thiokol using a method of verification to be presented in the verification plan and used only after approval of the procuring activity.

10.3.6 Mass Properties Report Plan

Reports will be submitted by Thiokol in accordance with MIL-M-38310A unless altered by this document or the procuring activity.

Reports submitted during the acquisition phase shall be as required in Table 10-4. Paragraphs quoted under "Tasks" and "Report Elements" are referenced from MIL-M-38310A.

Exceptions to MIL-M-38310A as shown in Table 10-4 include:

1. Deletion of the requirements to provide "parameters and inventory of fluids and propellants loaded" and "capacity and loading information for fluids and propellants" data from all reports since they are of primary use when dealing with liquid rocket motors.

2. Deletion of the requirement to provide in the first status report a "mass properties verification plan," an operational support plan for R & D, and a program plan. These plans will be submitted as separate procedural reports.

3. Deletion of the requirements to provide an operational support plan for orbital phase either as a separate report or in the first status report since the SRM Stage is used and jettisoned prior to orbital phase.

4. Deletion of the requirement to supply a detail report annually.

5. Deletion of the requirement to supply a "Fluid and Propellant Verification Plan" which is primarily for liquid rockets.

TABLE 10-4. REPORT CONTENT AND SUBMITTAL SCHEDULE

Program Phase					Acquisition															Operational
Report Type					Detail			Status						Procedural				Miscellaneous		Miscellaneous
Schedule of Submittals					At PDR, or within 30 days of approved definitive contract (or Go-Ahead) (FOR APPROVAL)	At CDR, or within 30 days after 90% completion of original drawing release for contracts of less than 2 years	At FACI or within 30 days after weighings, or flights, specified by the procuring activity	Design - first of each month after approved definitive contract (or Go-Ahead) and ending with delivery of last item	Pre-flight - 120 days prior to launch	Pre-flight - 14 days after acceptance weighing	Pre-flight - 14 days after significant mass properties change	Post-flight - Quick Look - within 24 hours after launch	Post-flight - Final - 30 days after launch	Program Plan - within 30 days after definitive contract (or Go-Ahead) (FOR APPROVAL)	Verification Plan - within 6 months after definitive contract (or Go-Ahead) (FOR APPROVAL)	Operational Support Plan - R&D within 6 months after definitive contract (or Go-Ahead) (FOR APPROVAL)	Operational Support Plan - Targeting - 12 months prior to scheduled activation of the system (FOR APPROVAL)	Contract Change Proposal - with each contract change proposal	Operational Targeting Data - as required by Operational Support Plan - Targeting	Operational Targeting Data - as required by Operational Support Plan - Targeting
Report Element	Tasks (para)	Page	Report Elements (para)	Page																
Title Page			3.4.3.1		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Table of Contents			3.4.3.2		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Introduction			3.4.3.3		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Contractor Mass Properties Organization	3.2.2.5		3.4.3.4		x	x														
Mass Properties Summary	3.2.3.9		3.4.3.5		x	x	x	x	x	x	x		x							
Detail Mass Properties	3.2.3.9		3.4.3.6		x	x	x													
Mass Properties Change Analysis	3.2.3.7, 3.2.4.2.6		3.4.3.7.1		x	x	x	x	x	x	x		x							
Trade Data	3.2.1.1, 3.2.3.6		3.4.3.32		x	x	x													
Pending Mass Properties Change Analysis	3.2.3.1, 3.2.3.7		3.4.3.7.2					x	x	x	x							x		
Summary of Improvement Potentials	3.2.4.2.2		3.4.3.7.3					x												
Unresolved Problems	3.2.4.2.3		3.4.3.8					x	x	x	x	x	x							
Mass Properties History Log	3.2.6		3.4.3.9				x		x	x	x		x							
Sequenced Mass Properties Data	3.2.3.9		3.4.3.10		x	x	x	x	x	x	x		x							
Powered Flight Mass Properties	3.2.3.9		3.4.3.11		x	x														
Diagrams	3.2.3.9		3.4.3.12		x	x	x	x	x[1]	x+	x+		x[1]							
Mass Properties Substantiating Data	3.1.2		3.4.3.13		x													x		
Government Furnished Equipment	3.2.3.4		3.4.3.14		x	x	x				x		x							
Computer Cards or Tapes	3.2.3.5		3.4.3.15		x	(x)	(x)	(x)												
Mass Distribution	3.2.3.9		3.4.3.16		x	x	x													
Mass Properties Dependent Design Information	3.2.3.1, 3.2.3.9		3.4.3.17.1		x	x	x	x												
Structural Increments for Design Features	3.2.3.1, 3.2.3.9		3.4.3.17.2		x		x													
Records for all Measurements	3.3.4, 3.3.5, 3.3.6		3.4.3.18.1				x			x	x		x							
Records for Dry Mass Properties Measurements	3.3.4, 3.3.5, 3.3.6		3.4.3.18.2				x			x										
Records for Fluid Mass Properties Measurements	3.3.4, 3.3.5, 3.3.6		3.4.3.18.3									x	x							
Summary of Critical Mass Properties	3.2.3.9		3.4.3.19					x	x	x	x	x	x							
Evaluation of Flight	3.3.7		3.4.3.20									x	x							
Critical Mass Properties Uncertainties	3.2.3.2		3.4.3.21		x	x	x													
Mass Properties Limits	3.1.2, 3.2.3.1		3.4.3.22		x	x	x													
Parameters and Inventory of Fluids and Propellants Loaded	3.1.2, 3.2.4.1		3.4.3.23						x	x	x	x	x							
Capacity and Loading Information for Fluids and Propellants	3.1.2, 3.2.4.1		3.4.3.24																	
Mass Properties Verification Plan	3.3.1, 3.3.2		3.4.3.25												x					
Operational Support Plan for R&D	3.2.2.2		3.4.3.26													x				
Operational Support Plan for Orbital Phase	3.2.2.2		3.4.3.27																	
Proposed Statement of Work	3.2.2.6		3.4.3.30														x			
Operational Support Plan for Targeting	3.2.2.2		3.4.3.28																	
Operational Targeting Data	3.2.2.2		3.4.3.29																x	x
Program Plan	3.2.2.1		3.4.3.31											x						

NOTES:

1 less item h
+ update only - submit changes to the data, information or analyses contained in the last published report of these items
(x) submitted as required by procuring activity

10.3.6.1 Mass Properties Reports

As a substitution for the mass properties history log required for each SRM, Thiokol will provide a "Weight and Balance Record Report," an "Actual Weight and Balance Report," and a "Sequential Mass Properties Report."

10.3.6.1.1 Weight and Balance Record Report

The Weight and Balance Record Report will provide actual weight and measured or calculated cg data of the end item as shipped. The report will become a part of the contract end item log and will remain with the contract end item until it is fired. Responsible personnel will use this report to maintain weight and balance control in the field.

Following is a brief summary of the data that will be contained within the Weight and Balance Record Report and a sample of the proposed format.

1. Title Page--The title page contains the title of the report, the serial number of the end item and approval signature.

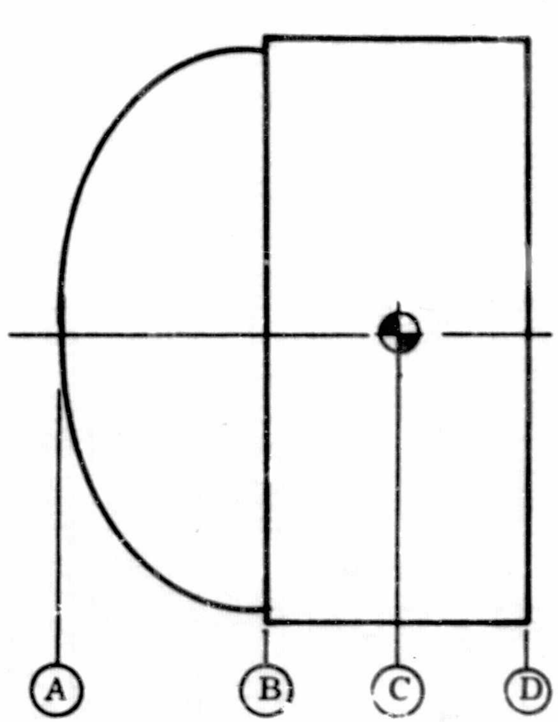
2. Introduction--The introduction will contain a brief description and intended usage of the charts and forms contained within the report.

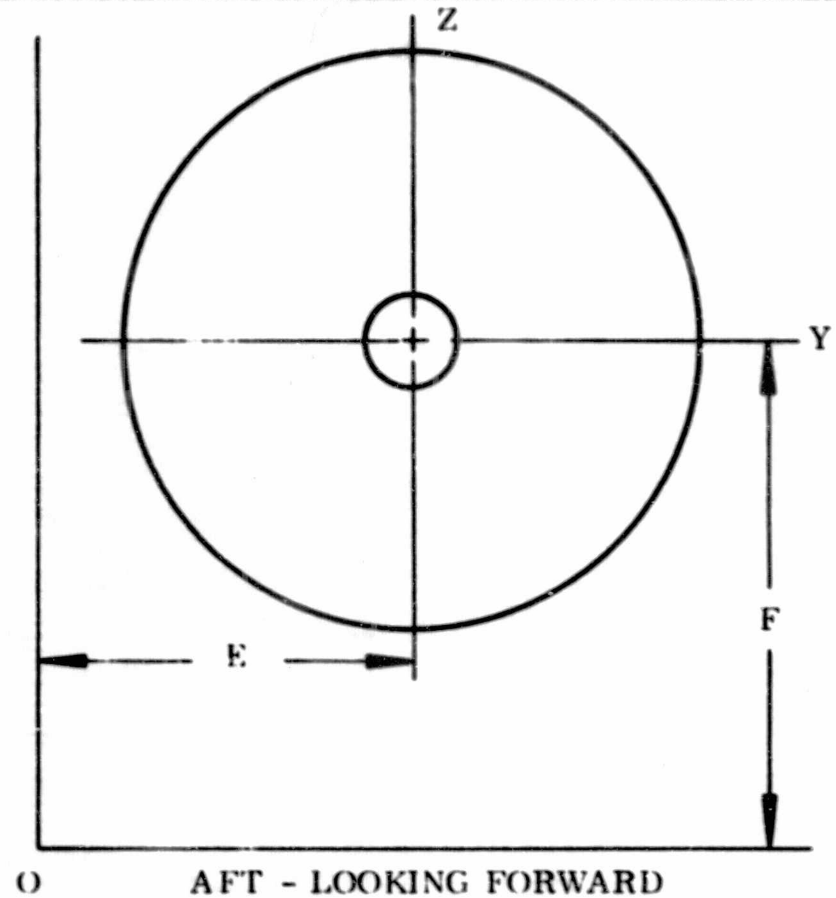
3. Center-of-Gravity Reference Diagram--This page will be for use by field personnel to locate items added or removed from the end item; it also provides pertinent end item dimensions (see Figures 10-4, 10-5 and 10-6).

4. Weight and Balance Data Sheet--This page will be used to determine the end item weights and center-of-gravity. These data will include harness components which support the end item at the time of weighing.

5. Component Weighing Check List--This page will provide weight and center-of-gravity of components added to or deducted from the end item weight as shipped (see Table 10-5).

6. Weight and Balance Change Record--This page will provide a tabulation, weight, arm, and moment of items added or deducted to derive the weights as shipped. This page also will be used to record times added or deducted in the field (see Table 10-6).

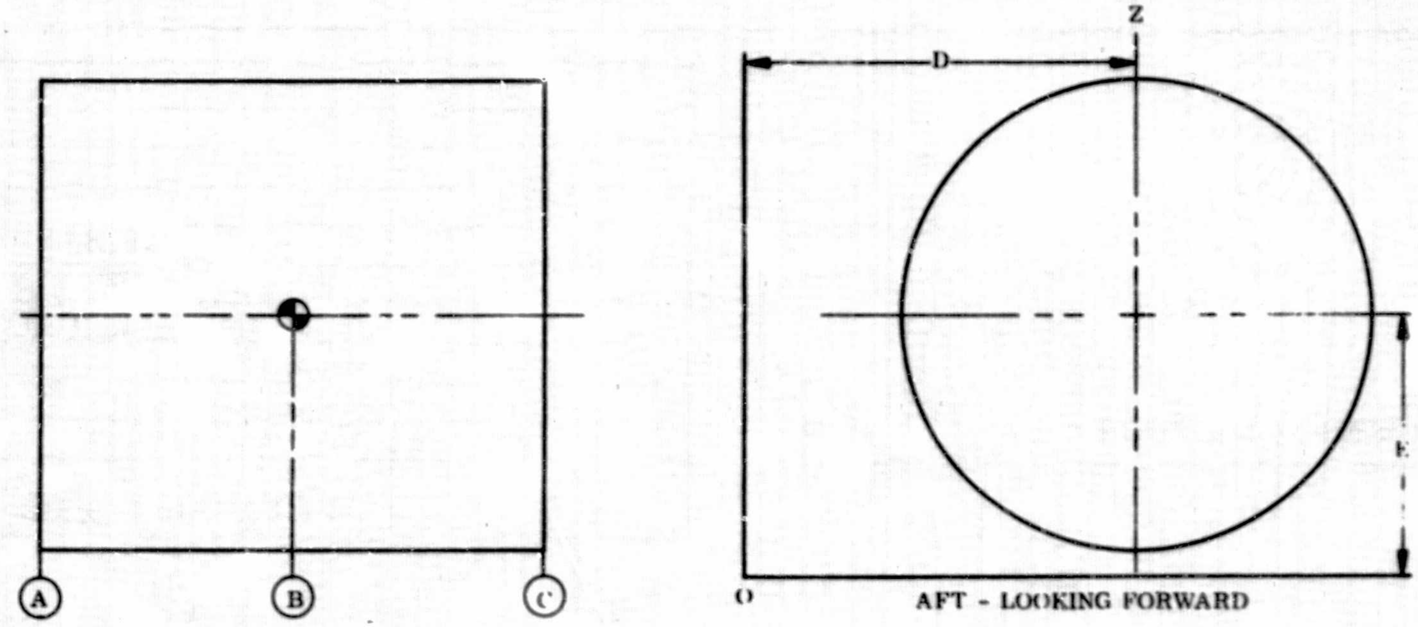




MOTOR/SEGMENT STA	
A	
B	
C	
LONGITUDINAL	
LATERAL	
VERTICAL	
D	
E	
F	
G	

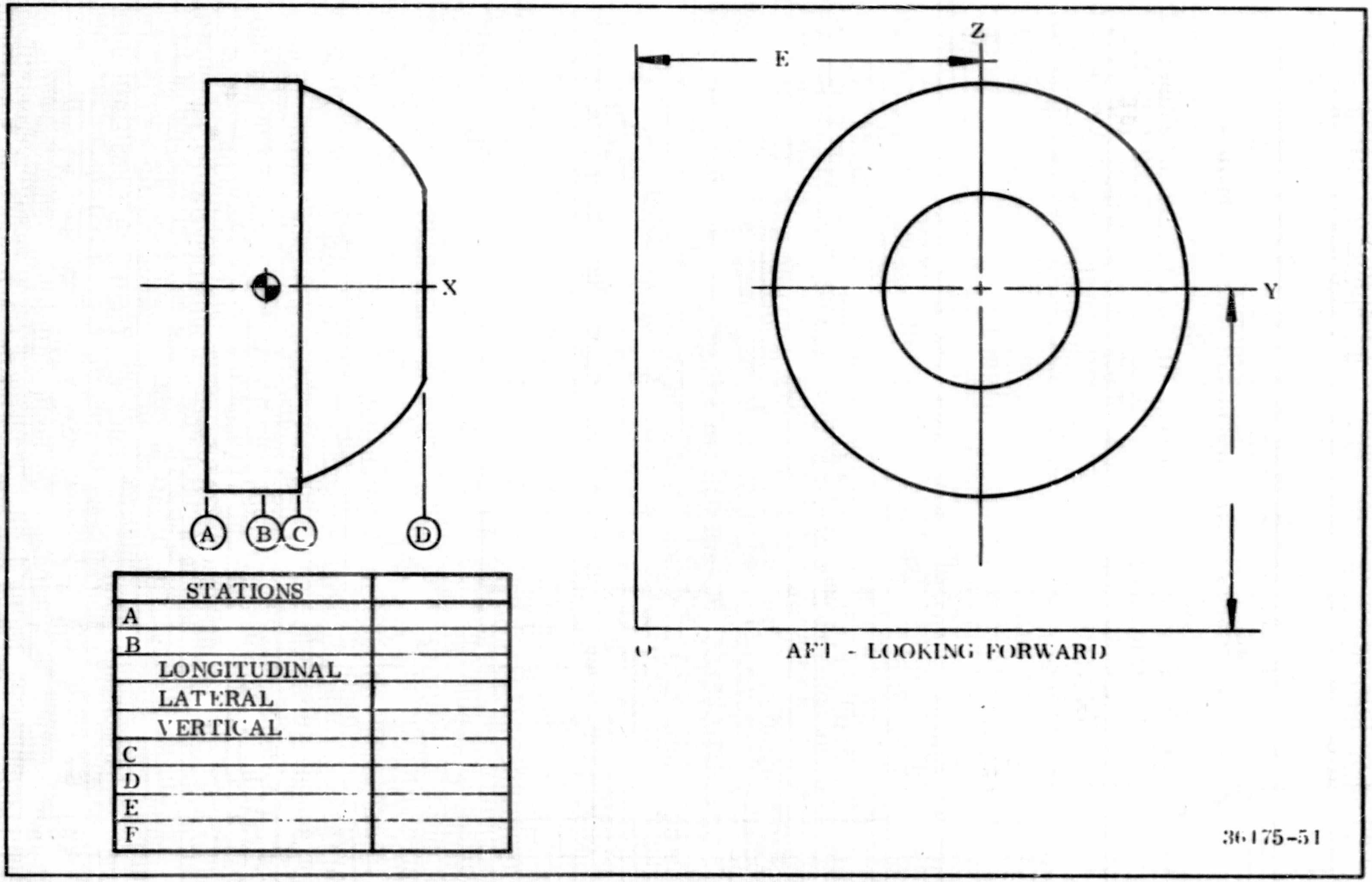
36175-50

Figure 10-4. Center of Gravity Reference Diagram - Forward Closure Assembly



CTR SEG NO. 1 STATIONS		CTR SEG NO. 2 STATIONS		CTR SEG NO. 3 STATIONS	
A		A		A	
B		B		B	
LONGITUDINAL		LONGITUDINAL		LONGITUDINAL	
LATERAL		LATERAL		LATERAL	
VERTICAL		VERTICAL		VERTICAL	
C		C		C	
D		D		D	
E		E		E	
F		F		F	

Figure 10-5. Center of Gravity Reference Diagram - Center Segment Assembly



STATIONS	
A	
B	
LONGITUDINAL	
LATERAL	
VERTICAL	
C	
D	
E	
F	

Figure 10-6. Center of Gravity Reference Diagram - Aft Closure Assembly

TABLE 10-5. COMPONENT WEIGHING CHECK LIST

CHECK LIST NO.

COMPONENT WEIGHING CHECK LIST

RECORD OF CHECKING (ENTER DATE)

PAGE OF COMPONENT

PART NO

MODEL NO ______ SERIAL NO. ______

USED ON MISSILE NO ______

ITEM NO.	COMPONENT OR HANDLING EQUIPMENT — DESCRIPTION	COMPONENT OR HANDLING EQUIPMENT — S N	WEIGHT	X AXIS	Y AXIS	Z AXIS	CHECK — BASIC WEIGHT	CHECK — AS WEIGHED	CHECK — REMOTE SITE SHIPMENT	CHECK — AS RECEIVED REMOTE SITE	CHECK	CHECK — LAUNCH

FORM TC NO. 973

TABLE 10-6. WEIGHT AND BALANCE CHANGE RECORD

WEIGHT AND BALANCE CHANGE RECORD

ASSOCIATE CONTRACTOR	____________	CONTRACT NO.	____________	REPORT NO.	____________
COMPONENT	____________	LOT NO.	____________	DATE	____________
MODEL NO.	____________	DRAWING NO.	____________	PREPARED	____________
SERIAL NO.	____________	U.O. MISSILE	____________	APPROVED	____________

EQUIPMENT CHANGE RECORD		WEIGHT AND BALANCE						
		WEIGHT	X AXIS		Y AXIS		Z AXIS	
S/N	DESCRIPTION OF EQUIPMENT		ARM	MOMENT	ARM	MOMENT	ARM	MOMENT

FORM TC NO. 971

7. Specification Comparison Page--This page will provide a comparison of the actual values to the specification values of weight and center-of-gravity (see Table 10-7).

10.3.6.1.2 Actual Weight and Balance Report

An Actual Weight and Balance Report will provide the actual weight and center-of-gravity of the components that make up a complete SRM.

Following is a brief summary of the data that will be contained within the Actual Weight and Balance Report and a sample of the proposed format.

1. Title Page--The title page will contain the title of the report, the serial number of the motor being reported on, and the approval signatures.

2. Introduction--The introduction contains a summary of the report contents and a summary of the motor weight and center-of-gravity.

3. Center-of-Gravity Reference Diagram--This page provides pertinent motor dimensions (see Figure 10-3).

4. Summary Mass Properties--This page will contain a summary of expended and unexpended weight, center-of-gravity, and moment of inertia (see Table 10-8).

10.3.6.1.3 Sequential Mass Properties Report

A Sequential Mass Properties Report will provide weight, center-of-gravity, and moment of inertia as a function of time (see Table 10-3).

10.3.6.2 Inputs to Other Reports

Thiokol will provide the following mass properties inputs to other reports.

10.3.6.2.1 Motor Test Plans

Thiokol will include in each motor static test plan the requirements for measurement and reporting of post-test mass properties prior to and during disassembly of each static tested motor.

10.3.6.2.2 Quick-Look Reports

Thiokol will include in each Quick-Look Report for each static tested motor the total motor (CEI Configuration), measured mass and center-of-gravity and the measured total motor propellant and inert weights.

TABLE 10-7. SPECIFICATION COMPARISON

SPECIFICATION COMPARISON			
DESCRIPTION	PARAGRAPH NUMBER	SPEC VALUE	ACTUAL VALUE

TABLE 10-8. MASS PROPERTIES SUMMARY SAMPLE FORMAT

BASELINE SOLID ROCKET MOTOR SPACE SHUTTLE 156 IN BOOSTER-PARALLEL BURN

	WEIGHT (LBS)	CENTER OF GRAVITY LONG.	LAT.	VERT.	MOMENT OF INERTIA PITCH	ROLL	YAW
CASE	102754.980	918.487	200.000	200.000	2951.267	130.792	2951.267
FORWARD SEGMENT	14395.715	382.327	200.000	200.000	16.934	17.215	16.934
CENTER SEGMENT 1	22943.254	609.375	200.000	200.000	49.373	29.955	49.373
CENTER SEGMENT 2	22943.254	890.875	200.000	200.000	49.373	29.955	49.373
CENTER SEGMENT 3	22943.254	1172.375	200.000	200.000	49.373	29.955	49.373
AFT SEGMENT	18950.505	1425.965	200.000	200.000	29.052	22.953	29.052
INSULATION	11905.618	925.203	200.000	200.000	595.198	13.010	595.198
EXPENDED PAT	0.949	286.019	200.000	200.000	0.000	0.000	0.000
EXPENDED TDAT	4076.941	920.789	200.000	200.000	199.781	4.404	199.781
FORWARD SEGMENT	1300.023	374.124	200.000	200.000	1.549	1.413	1.549
CENTER SEGMENT 1	468.640	606.018	200.000	200.000	1.862	0.587	1.862
CENTER SEGMENT 2	468.640	887.518	200.000	200.000	1.862	0.587	1.862
CENTER SEGMENT 3	468.640	1169.018	200.000	200.000	1.862	0.587	1.862
AFT SEGMENT	1370.999	1473.273	200.000	200.000	2.100	1.231	2.100
UNEXPENDED EAT	7827.727	927.579	200.000	200.000	395.307	8.605	395.307
FORWARD SEGMENT	2612.546	379.002	200.000	200.000	2.858	2.948	2.858
CENTER SEGMENT 1	827.304	609.736	200.000	200.000	2.355	1.075	2.355
CENTER SEGMENT 2	827.304	891.236	200.000	200.000	2.355	1.075	2.355
CENTER SEGMENT 3	827.304	1172.736	200.000	200.000	2.355	1.075	2.355
AFT SEGMENT	2733.269	1484.927	200.000	200.000	3.422	2.433	3.422
LINER	1277.973	912.128	200.000	200.000	36.395	1.582	36.395
EXPENDED PAT	3.370	878.975	200.000	200.000	0.098	0.004	0.098
FORWARD SEGMENT	0.534	388.281	200.000	200.000	0.001	0.000	0.001
CENTER SEGMENT 1	0.745	581.765	200.000	200.000	0.003	0.001	0.003
CENTER SEGMENT 2	0.745	863.265	200.000	200.000	0.003	0.001	0.003
CENTER SEGMENT 3	0.745	1144.765	200.000	200.000	0.003	0.001	0.003
AFT SEGMENT	0.603	1371.510	200.000	200.000	0.001	0.001	0.001
EXPENDED TDAT	636.271	888.673	200.000	200.000	25.759	0.754	25.759
FORWARD SEGMENT	180.724	377.361	200.000	200.000	0.203	0.199	0.203
CENTER SEGMENT 1	95.697	609.371	200.000	200.000	0.341	0.120	0.341
CENTER SEGMENT 2	95.697	890.871	200.000	200.000	0.341	0.120	0.341
CENTER SEGMENT 3	95.697	1172.371	200.000	200.000	0.341	0.120	0.341
AFT SEGMENT	168.456	1433.475	200.000	200.000	0.270	0.194	0.270
UNEXPENDED EAT	638.333	935.683	200.000	200.000	10.385	0.825	10.385
FORWARD SEGMENT	1.430	390.570	200.000	200.000	0.001	0.002	0.001
CENTER SEGMENT 1	192.927	609.259	200.000	200.000	0.244	0.249	0.244
CENTER SEGMENT 2	192.927	890.759	200.000	200.000	0.244	0.249	0.244
CENTER SEGMENT 3	192.927	1172.259	200.000	200.000	0.244	0.249	0.244
AFT SEGMENT	58.120	1356.475	200.000	200.000	0.045	0.075	0.045

MOMENT OF INERTIA IS IN SLUG FEET SQUARED DIVIDED BY 1000 ABOUT AXES
THRU THE CENTER OF GRAVITY

10.3.6.2.3 Final Motor Reports

Thiokol will include in each final motor report the following mass properties data about the motor.

1. A comparison of the measured motor mass properties and the contractual requirements.

2. The motor weight and balance summary showing major assembly weights of the motor in the as-built configuration, CEI configuration, post-fired configuration, and CEI end action time configuration.

3. A weight and balance record documenting the changes from the "As-Weighed" prefire and post-fired configurations to the "CEI Prefire" and "CEI End Action Time" configurations.

4. A center-of-gravity reference diagram.

10.3.6.2.4 Final Test Series Summary Reports

Thiokol will include in each Final Test Series Summary Report the following mass properties data.

1. A mass properties summary showing major assembly weights, total inert weight, total propellant weight, total prefire motor weight and three axis center-of-gravity data (CEI Configuration) and total end action time for each motor. It also will show the mean, standard deviation, and three sigma variation as calculated for the entire group of motors for each of the mass properties reported on individual motors.

2. A comparison of the group means and three sigma variations as calculated above with the contractual requirements.

3. Recommendations for changes in production mass properties limits based on the measured data shown for the entire group of motors tested.

10.3.6.3 Production Phase Reports

Reports submitted during the production phase will include:

1. Detail Report at FACI per column 11, Table 10-4.

2. Weight and balance record per paragraph 10.3.6 for each end item.

3. Actual Weight and Balance Report for each complete SRM.

4. Operational Targeting Data Report as required by the customer.

Table 10-4 constitutes the required schedule of submittals. The weight and balance record will be included in the motor log book with a copy being shipped with the end item. The Actual Weight and Balance Report will be submitted within 14 days after SRM assembly completion at the launch site.

10.3.6.4 Approvals

Procedural reports listed in Table 10-4 "(for approval)" must be approved by NASA. All others are for information only.

10.3.7 Actual Weight and Balance Program

Parts fabricated by Thiokol will be weighed according to special weighing procedures documents prepared by the mass properties engineer. The procedures documents, coordinated with planning and scheduling activities, will specify the item and assemblies to be weighed, the status of the assembly at weighing, the methods of weighing, recording, and forwarding actual weight data to the mass properties section. The implementation of these procedures will assure that precise and accurate mass properties will be provided on a timely basis.

All weighments at the contractor's facility will be performed on equipment that is certified by authorized specialists at scheduled intervals according to Specification MIL-C-45662A. Readout devices shall be capable of indicating weight as specified in Table 10-9. Equipment will be calibrated to an accuracy of $\pm 0.1\%$ of capacity.

Thiokol will design, develop, fabricate, or acquire the the test equipment required to measure the center-of-gravity of the assembled motor segments. The equipment will be designed to obtain the measurement accuracies needed to comply with the center-of-gravity limits specified by the customer.

TABLE 10-9. WEIGHING EQUIPMENT

Weight Range (lb)	Readout Increments (lb)
0-25	0.01
0-175	0.10
0-500	0.25
0-5,000	0.50
0-20,000	1.00
0-40,000	5.00

Detailed parts and subassemblies will be weighed in the shop as fabrication is completed. Major assemblies will not be weighed until they are at least 95% complete. A missing items list will be prepared at each major weighing so that missing item actual weights can be added when available.

Total SRM Stage weight and cg will be determined by combining the actual weight and measured or calculated cg data of the major assemblies and other individually measured items, and computing total characteristics.

Part weights taken in the shop will be recorded on a form which will give each part a unique identification (eg, drawing number, next assembly, nomenclature, Contract End Item (CEI) number, etc). Actual weight data will be taken from these records and placed in the accounting data storage and retrieval system. The data flow pattern is illustrated in Figure 10-2.

10.3.8 Field Program

Since weight data will be determined on all components before they leave the contractor's facility, no extensive field program is planned. A system will be developed whereby serial numbers of components changed in the field shall be forwarded to the mass properties section. These revisions will be incorporated and the revised mass properties report will be submitted to the customer. Implementation of this plan will provide critical performance mass property inputs for trajectory simulations which will be in agreement with the current configuration and planned propellant utilization.

10.3.9 Postflight Weight Analysis

The postflight weight analysis program will provide the capability for post-flight analysis to determine modifications needed in the critical performance weights to be used for succeeding flights.

Weight conditions at launch, determined as part of the Field Program will be compared to the final preflight weights. An evaluation will be made of the critical flight performance weights (minimum burnout, main impulse propellant, and weight at the start of web action time), and the uncertainties experienced.

10.3.10 Improvement Potential Program

A program will be established for the purpose of identifying areas of potential weight reduction. All significant outputs of this program will be included in the design phase mass properties status reports for review and final action by NASA.

11.0 LOGISTIC SUPPORT PLAN

11.1 INTRODUCTION

Thiokol Chemical Corporation will provide logistic support for the Solid Rocket Motor (SRM) Stage equipment during the site activation, flight test and production programs. This effort will include depot level maintenance and overhaul support at Thiokol's or the vendor's facilities and site level maintenance support.

Thiokol will provide adequately trained and certified personnel to perform the inspection, checkout, calibration, maintenance and operations support functions for the SRM Stage equipment. Spare support to satisfy the maintenance and overhaul requirement of the SRM Stage and associated ground support equipment (GSE) will be provided.

Modes of transportation, including methods of packaging and preservation of hardware, will be provided which best satisfy the system requirements.

This Logistic Support Plan will be used as the basis for implementing, in conjunction with NASA, Thiokol's Logistics Program. The procedures contained herein will provide the Management tools required for efficient and economical utilization of human and material resources in the performance of an integrated logistic support program.

11.2 OPERATIONAL SUPPORT

Thiokol will develop Logistic Support concepts and requirements at the earliest possible time in the program. This will assure the timely delivery of ground support equipment, operation and maintenance manuals, spare parts, etc, to support the SRM Stage. Upon receipt of contract go-ahead Thiokol will implement a system requirement analysis, operations analysis, and maintenance engineering analysis program to develop detailed Logistic Support requirements and equipment as a parallel effort to the SRM Stage verification program.

The following paragraphs define (1) a recommended preliminary Logistic Support concept, (2) a preliminary operational ground support equipment list, (3) technical manual development and (4) a preliminary list of recommended spares to support the operational site.

11.2.1 Operational Support Equipment Concept

Operational Support is defined as all required support of the SRM Stage from SRM Stage shipment from Utah, through delivery to the Kennedy Space Center (KSC), to completion of the assigned mission. To form a basis for

developing ground support equipment requirements, the following assumptions were made.

1. On pad maintenance will consist of removal and installation of modules or subassemblies. Removable items are listed as spares under paragraph 11.2.4 below.

2. Ordnance unit checkout after space shuttle vehicle integration will be limited to monitoring to assure safe or arm condition and connector mating integrity.

3. The integrated space shuttle system orbiter or ground power will furnish all required excitation and stimuli to perform a complete functional check of the Thrust Vector Control system after SRM Stage/Space Shuttle integration.

4. Maximum assembly of SRM Stage components will be accomplished prior to transfer to the VAB for SRM buildup.

5. All components coming from vendors directly to the KSC will be packaged for shipment by the vendor and shipped via common carrier.

6. The facilities used for assembly of the Space Shuttle Vehicle will be capable of lifting a 200-ton load.

7. A railroad extension will be provided from the existing railroad to a building (RISS Building) to be built near the Space Shuttle Vehicle Assembly building.

8. A roadway will be built from the new RISS building to the Space Shuttle Vehicle Assembly building that will handle approximately 400,000 lb loads.

9. Checkout of the SRM before integration with the Space Shuttle will be accomplished to the maximum extent possible to preclude a tear-down due to anomalies found during combined system tests.

10. Ordnance safe and arm devices will not be installed until after the combined system tests. Simulators will be used to this point.

11. All shipment of SRM segments to the KSC will be via railroad.

12. A low pressure test of the assembled SRM will be required to check for leaks in the SRM.

13. The support base on which the SRM Stage is assembled will have capability for SRM vertical alignment.

14. The support base will be provided by NASA.

15. Maintenance will be performed either at the site, at Thiokol/Wasatch, or at the vendor, as applicable.

The above listed assumptions form a basis from which the preliminary system requirements analyses (SRA), performed as a part of this contract, were generated. Those items of GSE identified along with other data contained herein are results of the preliminary SRA and these assumptions. After contract award for future work, as changes occur to the assumptions or additional facts are generated, appropriate changes to the SRA and consequent changes to the lists, etc, herein will be made.

11.2.2 Ground Support Equipment List

The following preliminary list and description of GSE have been defined, through a preliminary operations analysis, for use for SRM shipment from Thiokol/Wasatch to the KSC and throughout all operations at the KSC.

1. Ordnance Test Set--The ordnance test set will be used to completely test all ordnance units and associated cabling used on the SRM Stage. This will include cycling time, squib and motor resistance, continuity resistance, and hi-pot leakage resistance. Test currents will be fail-safe limited to prevent inadvertent firing of electro-explosive devices.

2. Electrical System Checkout Set, Rocket Motor--The electrical system checkout set will consist of all necessary adapters, connectors, etc, to provide for checkout of accelerometers, temperature sensors, and pressure transducers. The unit will check all transducers used on the SRM Stage using actual stimuli where possible to assure proper transducer operation. It will detect stray voltage in the electrical system and check continuity of combined SRM electrical circuits.

3. Safe and Arm Device Simulator--A safe and arm device simulator will be used to facilitate a complete checkout of the SRM Stage/Space Shuttle interface during combined system tests. The test will include checkout of safe and arm signals and firing voltages and currents.

4. Semitrailer--A semitrailer will be used to support, restrain, and protect the SRM segments from dynamic environments during transportation from Thiokol/Wasatch to the railhead at Corinne, from the railhead at KSC to the RISS building and from RISS building to the VAB.

5. Tiedowns--Tiedowns will be used during rail and highway transport.

6. Electrical Lead--Electrical leads are required to provide static electric grounding of the SRM segment during transfer.

7. Tractor--A tractor is required to provide mobility to the semitrailer.

8. Breakover Stand--A breakover stand is required to support SRM segments and break these segments over from horizontal to vertical with the use of a crane and lifting devices.

9. Segment Lifting Device--A segment lifting device is used to lift the segments in transfer and assembly operations.

10. Support Chocks--Support chocks are required to support the SRM segments during highway and rail transport.

11. Rocket Motor Leak Test Set--A test set is required to enable the assembled SRM to be leak checked, at low pressure, after assembly.

12. Work Platform--Work platforms are required to enable inspection, subassembly, assembly preparation, and SRM assembly operations.

13. Nozzle Alignment Set--A nozzle alignment set is required to enable nozzle checkout and alignment with the Shuttle vehicle.

14. Storage Chocks--Chocks are required at the storage area to support the SRM segments.

15. Protective Cover--A protective cover will be used over the SRM segments during shipment to prevent damage to the case and propellant.

16. Battery Charger and Test Set--The battery charger and test set will be used to charge the SRM airborne batteries and check the charge level of the batteries at various times.

17. Dummy Storage Battery--The dummy storage battery will be used to permit system electrical checkout without using the airborne batteries.

18. Electrical Cable Test Set--All electrical cabling will have end-to-end continuity checks using the electrical cable test set.

19. Ladder, Nose Cone--Access to the assembly points for various components that are in the nose cone will be provided by using the nose cone ladder.

20. Shipping Container, Nose Cone--A container for nose cone shipment will be provided.

21. Lifting Adapter and Lifting Sling, Nose Cone--In order to handle and lift the nose cone, all adapter and slings used will interface with the facility crane.

22. Nozzle Shipping Links--Shipping links are required to secure the nozzle during shipment of the aft segment with nozzle on.

23. Case Stiffeners--Stiffeners for case shipment and handling will be required at the case joints.

24. Shipping Containers, S & A Device--Containers for shipping safe and arm devices will be provided.

25. HPU/Nozzle Test Set--A test set will be required to check out the HPU and HPU/nozzle during operations at the RISS building and Vehicle Assembly building.

26. O-Ring Fabrication Tool--An O-ring fabrication tool will be needed for fabrication of O-rings used in SRM assembly.

27. Lifting Beam, Loaded Segment--A lifting beam which interfaces with the segment lifting device and the 200-ton cranes will be provided.

28. Lifting Sling--Miscellaneous lifting slings will be required for handling components during assembly and subassembly operations.

11.2.3 Technical Manuals

As a result of the SRA, operations analysis, and MEA, the requirements and required content of the operation and maintenance manuals, calibration and test procedures, checkout procedures, etc, are identified. These manuals will be prepared in accordance with Thiokol standard procedures and NASA requirements. The manuals will enable a technician to properly operate, assemble, check out and maintain all subsystems and components of the SRM Stage.

11.2.4 Spare Parts List

The following is a preliminary SRM Stage spare parts list for those items required at KSC to support production of the Space Shuttle Vehicle.

Qty	Name
TBD	Safe and arm devices
TBD	Electrical cabling
TBD	Raceway covers
TBD	HPU
TBD	TVC Actuators
TBD	Battery Set
TBD	Assembly Hardware
TBD	Power Distribution Box
TBD	Ordnance Distribution Box
TBD	Recovery System Components
TBD	Thrust Termination System Components
TBD	Attach Structure Components

In addition, the following spare parts will be required for the GSE: TBD

11.3 MAINTENANCE

Thiokol will satisfy the maintenance requirements for the SRM Stage system through establishment of a system maintenance program. This program will assure system readiness of the SRM Stage and provide effective support for both ground and airborne systems. The maintenance program will enumerate all system support action required for retaining or restoring the equipment to an acceptable operating condition.

11.3.1 Maintenance Program

Upon contract award a maintenance analysis will be conducted on a parallel basis with the SRM Stage verification program. Maintenance functions and requirements will be developed for all items of flight hardware and ground support equipment in accordance with NASA requirements. The maintenance requirements will be coordinated with the maintainability programs. These data will be incorporated as qualitative maintainability requirements to minimize complexity, design for minimum quantity of tools and test equipment, and provide optimum accessibility. Maintenance time predictions will be provided by maintenance engineering for comparison with the apportioned maintenance times established in the quantitative maintainability analyses.

Subsequent to the development of maintenance functions and requirements, the list of maintenance equipment needed to support the systems operation will be completed and recorded in the Configuration Items list. Maintenance loading will be established as a result of trade study analysis of equipment, spares, and personnel required to effectively maintain Thiokol's equipment. The correlation of the equipment, spares, personnel and queuing of maintenance requirements will establish the total maintenance ground equipment (MGE) and maintenance personnel required at the site and depot maintenance locations.

The equipment and personnel quantities and maintenance loading data will be submitted for review by NASA. Technical direction from this review will permit a Preliminary Design Review (PDR) of the design approach for the maintenance facilities and maintenance equipment. Based upon the results of the PDR, i.e., approval or incorporation of changes that may be recommended, the design of the maintenance equipment and facilities will be initiated. The design of the maintenance equipment will be coordinated by maintenance engineering personnel and will reflect any changes required to provide maximum system effectiveness. During design of the equipment, Thiokol will, as contractually directed by NASA, prepare calibration, certification, and measuring standards to be utilized at site or depot level maintenance.

Based upon system engineering documentation, Thiokol will, with approval of NASA, establish final quantity requirements for equipment. End item maintenance documentation will be used as the criteria for establishing MGE quantities.

Based upon the approved quantities of equipment and maintenance loading, the selection and identification of spares quantities will be established. These spares quantities will be sufficient to support the Integration and Checkout during DDT&E and production for the SRM Stage.

The Functional Configuration Audit (FCA) for operations and maintenance equipment will be conducted by Thiokol as specified by NASA. Successful completion of the FCA will initiate production of the equipment required in the program.

Demonstration and verification of operations and maintenance equipment will be accomplished as specified by NASA. The Physical Configuration Audits (PCA's) are required prior to acceptance test/verification. All changes to the equipment subsequent to the PCA will be accomplished by means of ECP's. Installation and checkout and test procedures will be reviewed to assure the maintenance requirements are satisfied.

Evaluation and verification of the maintenance task times established for the SRM Stage will be initiated during the installation and checkout of Thiokol's equipment. Completion of the evaluation and verification of the maintenance task times will be accomplished during the flight test program, however, special hardware tests will not be performed. The maintenance task times will be compiled during activation and flight test periods, utilizing maintenance activity required for the SRM Stage and systems support hardware. The compilation of the task times will serve for consideration of design and/or maintenance planning during the operational phase of the SRM Stage.

11.3.2 Maintenance Responsibilities

System support for maintenance of the SRM Stage will be provided by Thiokol in accordance with the specified launch requirements. Launch site maintenance will be the responsibility of Thiokol's launch operations organization. The responsibility for depot maintenance is assigned to Thiokol's manufacturing organization.

Prime responsibility of this launch site maintenance organization is to assure systems readiness of the SRM Stage. This readiness will be accomplished primarily through planning, scheduling, and controlling maintenance of the ground systems such that any required maintenance will not interfere with planned operations of the airborne systems. For the airborne systems, the launch site responsibility will be to maintain the launch readiness requirement of the SRM Stage and, if required, perform corrective maintenance to return the SRM Stage to an operational status within a specified period of time. The launch site maintenance program will be coordinated with NASA to assure timely and efficient achievement of the maintenance activities. During the flight test program, the launch operations personnel will establish design and maintenance criteria for incorporation in the

maintainability program. These criteria will be based upon knowledge gained in Thiokol's solid rocket motor programs (Minuteman) and advanced research programs on 120 in. and 156 in. diameter solid motors.

The depot maintenance organization will be responsible for establishing and sustaining the capability for returning the ground and flight systems to a serviceable status with specified tests and maintenance equipment, within a specified period of time and at a specified percent of unit cost. The requirements for depot maintenance and material support will be accomplished within the manufacturing organization of Thiokol. Thiokol will establish the required maintenance support for the SRM Stage including maintenance facilities, maintenance procedures and training, and spares handling and storage. Coordination will be maintained with the systems design and maintainability program personnel to assure compatibility with the maintenance program requirements.

11.3.3 Maintenance Levels

The contractor will implement the maintenance program to support two discrete maintenance levels, i.e., site and depot maintenance.

11.3.3.1 Site Maintenance

The basic philosophy for the site maintenance program is to conduct both scheduled and unscheduled maintenance for the ground support equipment (GSE) and to conduct only unscheduled maintenance for the airborne equipment. The scheduled maintenance program for the GSE will provide procedures for inspection, testing, servicing, calibration, and reconditioning the equipment at regular intervals. The objective of this preventive maintenance program is to prevent equipment failures in service, and to retard wearout deteriorations. During the design and verification program the maintenance engineering group will establish the periodic maintenance program for the ground equipment, based upon calendar or use time for each item. This periodic maintenance program for the launch site does not include overhaul. All overhaul activities associated with the ground support equipment will be conducted at Thiokol's or vendor's facilities. As stated previously, the maintenance program for the airborne equipment will be unscheduled maintenance. This unscheduled, i.e., corrective maintenance, will be performed to restore the airborne equipment to a specified operating condition, within a specified time, such that system readiness of the SRM Stage will be assured. Maintenance engineering will coordinate with the maintainability program to establish criteria for corrective maintenance of the airborne equipment. This criteria will include qualitative and quantitative requirements and will be directed at achieving maximum effectiveness of the maintenance resources.

Subsequent to FACI, the launch site maintenance program will operate under the principle of management by exception. This implies that actions or incidents which vary markedly from established standards will be singled out or

"excepted" for special management consideration. This includes subsystems and/or components which consistently fail to attain readiness standards, and subsystems and/or components which have an abnormally high maintenance support index. All "excepted" items would be evaluated through design reviews, and corrective designs will, with the approval of NASA, be incorporated. This process of management by exception is particularly adaptable to data processing techniques wherein historical documentation of maintainability index would be provided for management control of the maintenance program.

Two items of special consideration for the site maintenance program are the use of mobile maintenance teams, and the philosophy of cannibalization as a source for replacement of components. In the event that problem areas do arise, selected individuals from Thiokol's or vendor's facilities would be utilized for on-site inspection and evaluation, with the maintenance activities being accomplished by Thiokol launch operations personnel as part of the site maintenance. The requirement for cannibalization, as a source for replacement of components, is dependent upon the spares provisioning program. An adequate processing and provisioning program will be implemented to eliminate any requirement for cannibalization.

11.3.3.2 Depot Maintenance

The depot maintenance program will be conducted at Thiokol's or vendor's facilities. Objective of the depot maintenance program is to directly support the site maintenance activities through an effectual provisioning of the ground and airborne systems. Depot maintenance activities include overhaul, repair, and testing of unserviceable items commensurate with a specified criteria for replacement based on a percentage of end item cost. During the design and verification program, criteria for repair or replacement will be established. In addition, the maintenance engineering activity during these early months will include coordination with the design and maintainability program, establishment of maintenance cycles, and establishment of maintenance procedures. The logistics cycles will be established based upon predicted MTBF systems requirements and periodic systems requirements for the ground and airborne items. As the systems operating and maintenance characteristics become known, the logistics cycles will be varied to sustain sufficient replacement items for site maintenance activities.

11.3.4 Maintenance Cycles

The contractor will establish the scheduled and unscheduled maintenance requirements for the airborne equipment and GSE, as applicable. The systems maintenance requirements will be developed utilizing NASA required documentation. These data will be summarized to identify and correlate frequency of maintenance occurrences and personnel, MGE, and spares provisioning. The compilation of calibration requirements will be integrated in the maintenance task analysis to define measuring and alignment standards.

For the initial phase of the flight test program, the scheduled maintenance times will be based on anticipated equipment utilization and equipment MTBF data. As the equipment is utilized in the program, operational availability data will be utilized to update the scheduled maintenance tasks.

11.3.5 Maintenance Disposition

The airborne equipment and GSE of the SRM Stage normally will be restored to an acceptable operating condition by providing removal and replacement of items that have malfunctioned. However, it may be deemed necessary, based on systems readiness requirements, to perform onsite repairs of the equipment. The standard disposition for establishing whether an item will be repaired or replaced will be through utilization of malfunction reports (MR's) and material review actions (MRA's). The MR and MRA systems provide documentation and authorization for each replace/repair action performed. Items which have malfunctioned and are not repaired at the launch site will be shipped to Thiokol's facilities. At Thiokol's facility, the item will be processed for disposition using the launch site prepared MR and MRA forms. A Material Review Board composed of Thiokol engineering and quality and government quality representatives will review the returned items and recommend final disposition, i.e., failure analysis, scrap, modify, or restore to an operational status. All modified or repaired items will be processed through Thiokol's or the vendor's facilities for restoration and subsequently will be quality accepted and introduced back into the program.

11.3.6 Calibration

The alignment and/or adjustment of the ground and airborne equipment installed at the launch site will be accomplished using portable calibration equipment when and wherever practical. Ground and airborne equipment that must be removed or equipment which may require special calibration will be transported to either a calibration laboratory at the launch site or an off-site calibration facility. Any operations equipment that requires off-site calibration will be replaced prior to shipment for calibration unless it can be ascertained by Thiokol, with the cognizance of NASA, that operational readiness of the SRM Stage will not be degraded if the equipment is not replaced during the time of calibration. Accordingly, each item in this special requirements category would be reviewed and approved separately by the cognizant authority.

11.3.7 Maintenance Procedures

Effective and comprehensive preventive maintenance procedures (PMP) will be established for inspection, testing, and reconditioning of the ground and airborne systems. The procedures will enumerate personnel, skills, MGE utilization, and time requirements including frequency and time for repair for each item considered. The personnel to be employed in the preventive maintenance program will be trained with respect to performing the routine preventive maintenance tasks such as lubrication, calibration, and cleaning. In addition, the personnel will be trained to recognize potential problems such as corrosion, contamination, or other system degradation that may require

special maintenance. Documentation of the special requirements will be maintained and, where applicable, special procedures will be established to minimize problem areas and assure systems readiness of the SRM Stage equipment. Maintenance procedures will be developed in accordance with NASA requirements.

11.3.8 Maintenance Records

The operations and maintenance status and historical records for SRM Stage ground and airborne equipment for which Thiokol is responsible will be maintained in accordance with NASA requirements. A systematic method for documentation of equipment status will be used including: operations, replacement, maintenance, and modifications. Thiokol will implement these requirements by establishing standard procedures for maintaining the records, and training personnel in the use and compliance with the recording procedures. Personnel authorized to inspect and/ or sign exceptional release of repaired equipment will be designated by Thiokol.

The calibration requirements documentation that will be prepared during the design and verification program will establish the calibration requirements for the SRM Stage equipment. Those items which impose requirements on NASA calibration facilities will be coordinated with NASA during the flight test program to assure compatibility. In addition, periodic calibration requirements will be scheduled with the appropriate facility so that calibration can be accomplished on a noninterference basis if practicable.

11.3.9 Maintenance Facilities

11.3.9.1 Calibration Facilities

Two calibration facilities will be utilized by Thiokol for onsite calibration of ground and airborne equipment. The primary calibration laboratory will be the government operated Precision Measurement Equipment Laboratory (PMEL). The PMEL will be used for calibration of test equipment, i.e., government standard, commercial standard, or SRM peculiar equipment, which present calibration requirements within the capabilities of PMEL.

The secondary, or emergency, calibration laboratory is to be provided by NASA. This calibration facility will be utilized for adjustment and/or alignment of SRM Stage operational equipment which is removed for calibration, and SRM Stage peculiar test equipment.

11.3.9.2 Depot Facilities

Contractors--Thiokol will accomplish the depot-level maintenance program through utilization of Thiokol's and/or vendor's manufacturing/repair facilities. The actual disposition of where the depot maintenance will be conducted, i.e., at

Thiokol's or the vendor's facilities, will be dependent upon the maintenance action required. The maintenance location will be established during preparation of the end item maintenance analysis.

Mobile Depot Team--In providing systems support of the SRM Stage, it is not anticipated that a mobile depot team will be required. However, in the event of some unforeseen happening, Thiokol will utilize a mobile team to effect the repair and return the system to a state of readiness in a minimum time with maximum efficiency. This team will be technical specialists, the makeup of which will be dependent on the required repair action.

Government-- Depot level repair and/or overhaul of GFP will be the responsibility of Thiokol on those items for which Thiokol has assigned maintenance responsibility and will be provisioned as required to sustain readiness of the launch site. Disposition for repair of an item will be authorized by the appropriate NASA Representatives. There are no system peculiar items of GFP identified in this plan that require authorization for approval of repair.

Site--Thiokol will conduct site level maintenance utilizing the RISS building to be built near the final assembly building.

11.4 SPARES

Spare parts requirements will be defined by Thiokol Chemical Corporation's maintenance analysis. The data derived from the maintenance analyses will support Federal stock number screening requirements and the preparation of reports and applicable documentation for the provisioning of spare parts. Factors that Thiokol will consider in the identification and selection of spare parts and quantities include, but are not limited to, the following: installation status; maintenance function; maintenance limitations of the equipment; functional area (maintenance at Kennedy Space Center or NASA, or maintenance performed at Thiokol Plant or vendor facility); source code (manufactured or procured), shelf life; reparable or nonreparable characteristics; repair cycle time. wearout rates (percentage condemnation of reparable item); percentage of operating time; calibration frequency; inspection frequency; consumption data and reliability history (failure rates and reports, reliability factors), units/assembly/installation total program usage; effectivity; need dates/program schedules; and lead time, cost, and experience with like type equipment. After careful consideration of the above, Thiokol will establish a recommended maintenance factor to be used in the following computational formula: recommended maintenance quantity factor (percentage of spares required to support one line item on one end item for one month) times the quantity of the line item used on one article times the number of end articles procured times the number of months of required support equals the total quantity recommended. Strict inventory controls, consumption reports, and failure reports established by Thiokol will be used for updating inventory levels at the applicable maintenance sites.

11.4.1 Spare Parts Selection

Items selected as spare parts will be screened against government furnished equipment parts lists, excess and long supply lists, Thiokol's records for common item assets available in our other government programs, and identification of existing Federal stock numbers. Department of Defense assets will be screened to insure maximum utilization of existing items. This will be accomplished by screening manufacturers' part numbers or Federal stock numbers against the Defense Logistics Service Center catalogue files for the purpose of revealing or validating Federal stock numbers. Items that are currently in government inventory will be requisitioned through the NASA Contracting Officer (NCO) as applicable to meet program need dates. Inventory levels will be programed to vary with anticipated usage and maximum utilization shall be made of existing assets.

11.4.2 Interim Release

Thiokol will interim release items of long lead time to insure delivery by predetermined need dates. Items identified as long lead time items will be interim

released in quantities providing adequate support at minimum inventory level so as to minimize obsolescence due to design changes. In effecting interim release action, Thiokol will not exceed the funds administratively reserved for spare parts when there is evidence of such reservation. Interim released items will be included in the first subsequent spare parts provisioning list not to exceed 30 days from the date of release. The interim release clause of the contract will be used only until such time as the first spare parts provisioning list is approved.

11.4.3 Preparation of Spare Parts Provisioning List (SPPL)

The Spare Parts Provisioning List will be prepared in accordance with NASA's provisioning acquisition documents. The provisioning list will be sectionalized per each end article being supported and will be an item number sequenced within each section. All interim released items and Federal stock numbered items will be identified. These lists will be updated at 30 day intervals, reflecting new recommendations, changes, deletions, prices, and item delivery status.

11.4.4 Item Numbering

Thiokol will assign item numbers in sequence to each spare part released or listed on the Spare Parts Provisioning List the first time the item is submitted. If a part is completely superseded, the numeric portion of the item number will be retained on the superseding part and the alpha indicator will be changed to the next consecutive alpha letter (e.g., 0001B). Alpha letters I, O and Q will not be used as part of the item number. Once an item number has been assigned to a part number, it will not be reassigned or used in relation to another spare part furnished under the same contract.

11.4.5 Receipt and Processing of Customer Spare Parts Orders

Upon receipt of spare parts orders in the form of the approved Spare Parts Provisioning List (SPPL), Thiokol will issue purchase orders to vendor for purchased items in accordance with applicable procurement specification or release manufacturing orders to shop units for Thiokol fabricated parts.

Incoming spare parts from vendors or individual Thiokol manufacturing units will undergo receiving inspection and testing operations in accordance with applicable specifications currently in use or new specifications that may be designated by NASA.

Upon completion of receiving inspection and/or flight acceptance test, the items will be placed in the Spares Bonded Stores.

Spare parts processed for Bonded Stores will be prepared for delivery in accordance with NASA's requirements for preservation, packaging and marking of

spares for protection against moisture, physical damage and other forms of deterioration during handling, shipment, and storage.

11.4.6 Priced Spare Parts List

Within 60 days after receipt of the approved SPPL, Thiokol will prepare and submit to the NCO a Priced Spare Parts List (PSPL) covering items and quantities ordered. The PSPL will be in the same format and sequence as the SPPL except the budgetary estimated prices will be replaced by firm prices.

11.4.7 Revision to Priced Spare Parts List

Thiokol will maintain the PSPL by preparing and submitting revisions as additional spare parts orders are received. These lists will be submitted to the NCO for approval at intervals no greater than 60 days.

11.4.8 Substantiation of Prices

The unit prices and extended unit prices listed on the PSPL and revisions thereto will not include charges for compliance with preservation, packing, and packaging requirements. These charges will be listed at the end of the lists and will reflect the total price for preservation, packing, and packaging of all items contained in the list. The price for all items listed on the PSPL and revision thereto will be totaled on the last page of each document. Thiokol will provide estimated cost breakdown (e.g., labor hours, material, procurement, etc.) in sufficient detail to substantiate the prices of major items listed on the PSPL and revisions thereto.

11.4.9 Cancellation Addendum

The charges incurred by Thiokol for spare parts subsequently canceled by NASA action will be included in a Cancellation Addendum and submitted to the NCO. Thiokol will endeavor to use those spares quantities cancelled by the government by diverting such quantities to production or other uses. The Cancellation Addendum will, if required, be prepared and processed in the same manner at the PSPL and appended to the list.

11.4.10 Spare Parts Exhibit

After the prices in the PSPL have been negotiated by the NCO, the list will be established as the Spare Parts Exhibit by Supplemental Agreement to the contract. As revisions to the PSPL are negotiated, they will be added as supplements to the Spare Parts Exhibit and the target cost, target profit, and ceiling prices appropriately adjusted.

11.4.11 Unit Price and Target Price

The "unit price," as used in the SPPL, the PSPL, the Spare Parts Exhibit and the supplements thereto, is defined as the unit cost of a spare without preservation and packing cost and without profit. The "target price" of an item will be the unit price shown in the Spare Parts Exhibit, or supplement thereto, plus a percentage factor to cover the preservation and packing cost and profit.

11.4.12 Material Management

A system to accomplish the functions of spare parts, property accounting, and inventory control will be developed and maintained by Thiokol.

11.4.13 Inventory Control and Spares Delivery

Thiokol will maintain property accounting records for all spare parts furnished under the terms of the contract. Item data records will be compatible with those used by NASA.

Spare parts will be delivered concurrently with end article deliveries and shall be in conformance with engineering drawings and/or specifications prior to release. Major components and spares will be stored in bonded storage areas at the maintenance locations. Provisions will be made to insure proper environmental control for flight components and ground support equipment spare parts consistent with anticipated transportation modes and normal storage conditions. Items requiring time cycle inspection or having a short term life span will be identified and shipped as such. Stock record and consumption recording will be governed and maintained by Thiokol's provisioning organization for all parts being controlled. Usage, as recorded from consumption reports received from maintenance site personnel, will be evaluated on a monthly basis to determine average monthly consumption for each part and to maintain proper inventory levels at the maintenance site. If an emergency condition exists for an item, the requirement will normally be met from available production stock. If this is not possible, the item will be handled on a priority basis.

The removal of a spare item from Thiokol Spares Bonded Store for shipment to KSC will be accomplished by completing a Shipping Request Form. This shipping form will direct the spares storekeeper to ship the item(s) to Thiokol's personnel at KSC. It will be the responsibility of Thiokol to select and use the method of shipment which will be most economical to the Government, considering the urgency of the individual shipment.

Upon receipt of the item(s) at the KSC, Thiokol personnel will:

1. Receive, store, issue and maintain custodial responsibility records.

2. Accomplish receiving and shipping actions and prepare applicable documentation.

3. Provide transportation, pickup and delivery services.

Spares will be issued to authorized personnel upon receipt of a malfunctioned or damaged component (except for consumables) accompanied by a signed requisition form.

Thiokol personnel at KSC will have the full responsibility for monitoring and issuing all spare parts and consumable materials. Each issue will be reported to the Thiokol plant for inventory updating. Spares quantities at the KSC will be maintained in accordance with an approved allocation list as listed in the Spares Monthly Status Report (SMSR). Thiokol personnel at KSC will check the SMSR upon receipt of each issue and report any variances to the Thiokol plant for corrective action.

11.4.14 Spare Parts Configuration Management

Thiokol spares provisioning organization will provide configuration control board representatives to obtain advance information concerning design changes or new engineering releases affecting spare parts recommended and/or on order.

If a design change occurs which affects any spare part on order, the spare part order will be prorated and/or adjusted to agree with the design change and the spare parts provisioning list updated accordingly.

Thiokol, in revising the quantity of spare parts on order as a result of a design change, will take into consideration all known factors such as design improvements, increased operating life, etc, which might warrant an overall reduction of the total quantity on order.

Spare parts that have been categorized as requiring serialization and control will be serialized in accordance with the customer requirements. This will include items that are reparable or subject to removal or replacement at a designated time and/or items removed for reliability evaluation.

11.4.15 Spare Parts Modification and Repair Cycle

All reparables generated at the site will be packaged and shipped to the Thiokol plant or vendor (as applicable) for disposition. The Material Review Board will recommend the optimum disposition (repair, modification, or scrap)

of returned items. Repair or replacement decisions will be based on need dates and repair costs as compared to replacement costs. Thiokol will perform an analysis for those items to be repaired to minimize the repair parts required and expedite their return to a serviceable condition. Outstanding modifications will be incorporated upon request of the NCO. Such modifications will be consistent with changes that have received prior approval from the configuration control board. Surplus and obsolete parts that cannot be economically repaired or modified will be reported for disposition.

11.4.16 Stock Balance and Consumption Report

From data contained in the property accounting records, Thiokol will maintain and furnish to the NCO a Stock Balance and Consumption Report as required by the contract or as directed by the NCO. The report will reflect as a minimum: item number, part number, Federal stock number. location, total ordered, and cumulative issues.

This will provide a management tool for replenishment of items and adjustment of the stockage position by comparing consumption against assets.

11.4.17 Lists of Spare Parts

Equipment supplied by Thiokol to another contractor having maintenance responsibility will be supplied with supporting documentation in the form of drawings, operating and maintenance procedures, and lists of recommended spare parts.

11.4.18 Data to Support GFP Spares Provisioning

Equipment furnished to Thiokol as Government Furnished Property (GFP) also will require data in the form of Government Furnished Equipment Parts Lists (GFEPL), drawings, operating manuals, and maintenance manuals. These lists will be screened for available assets and requisitioned through the NCO. Items appearing on the list that are required spares but are not currently available in government inventory will be listed on the SPSL and submitted to the NCO for approval.

11.4.19 Disposition of Excess and Surplus Property

Property which is no longer required to complete any portion of the contract will be analyzed by Thiokol to determine if the property can be used in support of other government programs. Spares that become obsolete because of engineering changes or failure will be analyzed for future application. Modernization cost will be weighed against factual and predicted requirements. The property will be considered for training purposes and breakdown for spares backup. Spares will not be termed excess until Thiokol is assured that further utilization is not

economically justified. If the property is determined in excess to all applications available to Thiokol, disposal procedures will be initiated in accordance with the terms of the contract. Items declared excess will be inspected for condition and stored until disposition instructions are received from the NCO.

11.5 PRESERVATION AND PACKAGING

Thiokol will prepare preservation, packaging, and packing data for configuration items, and spare parts to support requirements of the Space Shuttle SRM Stage. Coded data will be furnished on standard "Preservation and Packaging Data Forms" in accordance with NASA requirements. Preservation, packaging procedures, and material requirements will conform to NASA requirements.

Preservation compounds will not be applied to surfaces of items to be packaged which are protected with solid film lubricants, vitreous or plastic coatings, prime coated or painted, nor will they be applied to items fabricated from textiles, plastics, rubber, leather, or items such as prelubricated bushings, or certain types of electrical or electronic parts and equipment. Neither will preservation compounds be applied to items which would suffer damage to mechanisms or structures where malfunction or unsafe operational conditions would result due to applications or removal of preservative compounds, or if removal cannot be readily accomplished in the field.

End items will be protected for domestic shipment and immediate use. Packing will be the minimum required to adequately protect the items in view of the destination, mode of transportation, and anticipated storage conditions.

Items, sturdy enough to withstand shock and handling incurred during movement, will be shipped devoid of packing. Criteria established to identify such items will depend upon carrier requirements. Design criteria for packing will be in accordance with NASA requirements for packages weighing up to 250 lb gross. Delivery of such items devoid of packaging would result in significant saving in material and labor costs. Sturdy items, shipped for immediate use, would fall in this category.

In addition, Thiokol will prepare packaging designs for special or sensitive items which present special transportation, packaging, shock, vibration, environmental, or handling problems. Packaging designs will be prepared when the physical characteristics of the items being packaged require special blocking, bracing, cushioning, suspension systems, or specially designed nonspecification containers to provide the necessary protection. Basic isometric or perspective views will be used to show the various components of the package in relation to each other and the contained item. Design drawings will contain complete preservation and packaging instructions and will be prepared on Thiokol engineering drawing format.

Dangerous materials to be transported via military aircraft will be in conformance with NASA and/or military requirements as applicable. Any material that is an oxidizing agent and that by virtue of its properties is flammable, corrosive, combustible, explosive, toxic, radioactive, or unduly magnetic (sufficient magnetic field strength to cause aircraft compass deviation) are considered

dangerous materials. Such material will be packaged and packed in containers conforming to Department of Transportation Regulations. Deviations from standard packaging procedures may be authorized when dangerous materials are to be air-lifted in tactical or transport military aircraft, provided the policies are established by NASA and/or the Air Force.

Packaging and container marking will be in accordance with NASA requirements.

Personnel experienced in government packaging techniques, and well apprised of Federal specifications and Military standards, will administer packaging requirements.

11.6 TRANSPORTATION

This program will serve as the guideline for the safe and economical handling and transportation of SRM components, spares, GSE, component parts, reparables and facility equipment during the flight test and production programs.

It will function in compliance with Government regulations and regulatory boards as applicable and be fully coordinated with the cognizant transportation activities as required. The plan will be administered by Thiokol's Traffic and Transportation Department.

Analysis and trade study reports performed indicate that rail shall be used as the primary mode of transportation for oversize/overweight components. Highway transportation will provide the secondary mode or backup for the movements of the larger units as required. Other shipments will be made by the mode of transportation best adapted to provide the required service at the lowest cost to the Government.

Components assembled at Thiokol's Wasatch Division will be shipped to the launch sites by rail. Thiokol will load assemblies on heavy duty highway equipment utilizing a 200-ton mobile crane. Assemblies then will be transported by motor carrier to the rail head where they will be transferred to 200-ton capacity rail cars equipped with shock mitigating undercarriage and special tiedown attachments. The transfer will be made by an overhead bridge crane. Special tiedowns which comply with the applicable blocking and bracing requirements will be used to assure safe transportation of items. Reusable containers will be consolidated for the return movement to Utah thereby minimizing transportation costs. Loading of components on flatbed trailers will be accomplished directly from Thiokol's shipping dock using Thiokol owned and installed equipment.

Components shipped by rail to the KSC will remain on the rail cars until receipt-inspection. The processing at the RISS building will include transferring the segments from the special rail cars used in transcontinental shipment to

storage chocks. Components arriving by highway transporter will be off loaded at the RISS building.

A one time shipment of items of GSE will be made to support the site activation function at the KSC. A listing of GSE is found in Section 2.2 of this plan. The items which are overdimensional will be shipped by rail with motor carrier as a secondary mode. Other items of GSE will be shipped by the most economical method consistent with the requirements of the program.

Consolidation of these smaller items with the overdimensional components for shipment by rail will be analyzed to get maximum use of the transportation equipment and attendant cost savings.

Thiokol will prepare packaging designs for special or sensitive items which present special transportation, packaging, shock, vibration, environmental, or handling problems. Packaging designs will be prepared when the physical characteristics of the items being packaged require special blocking, bracing, cushioning, suspension systems, or specially designed nonspecification containers to provide the necessary protection.

11.7 TRAINING

The approach to personnel training for the SRM Stage operations is based on three factors:

1. The time element wherein personnel must develop capabilities concurrent with hardware.

2. The basic skills programed to phase into the program.

3. The previous experience of personnel that permits the implementation of such a program.

11.7.1 Thiokol Personnel Training Program

On the job training (OTJ) will be initiated in the motor verification phase followed by classroom training. The classroom training will phase in with the initial draft of operation, maintenance, and transportation procedures. This will insure that all necessary training will be completed in time to support the flight test program.

The training program will be implemented with selected field personnel gaining subassembly familiarization by active participation in, and observation of, manufacturing processes. SRM assembly techniques will be developed during verification program SRM static firings.

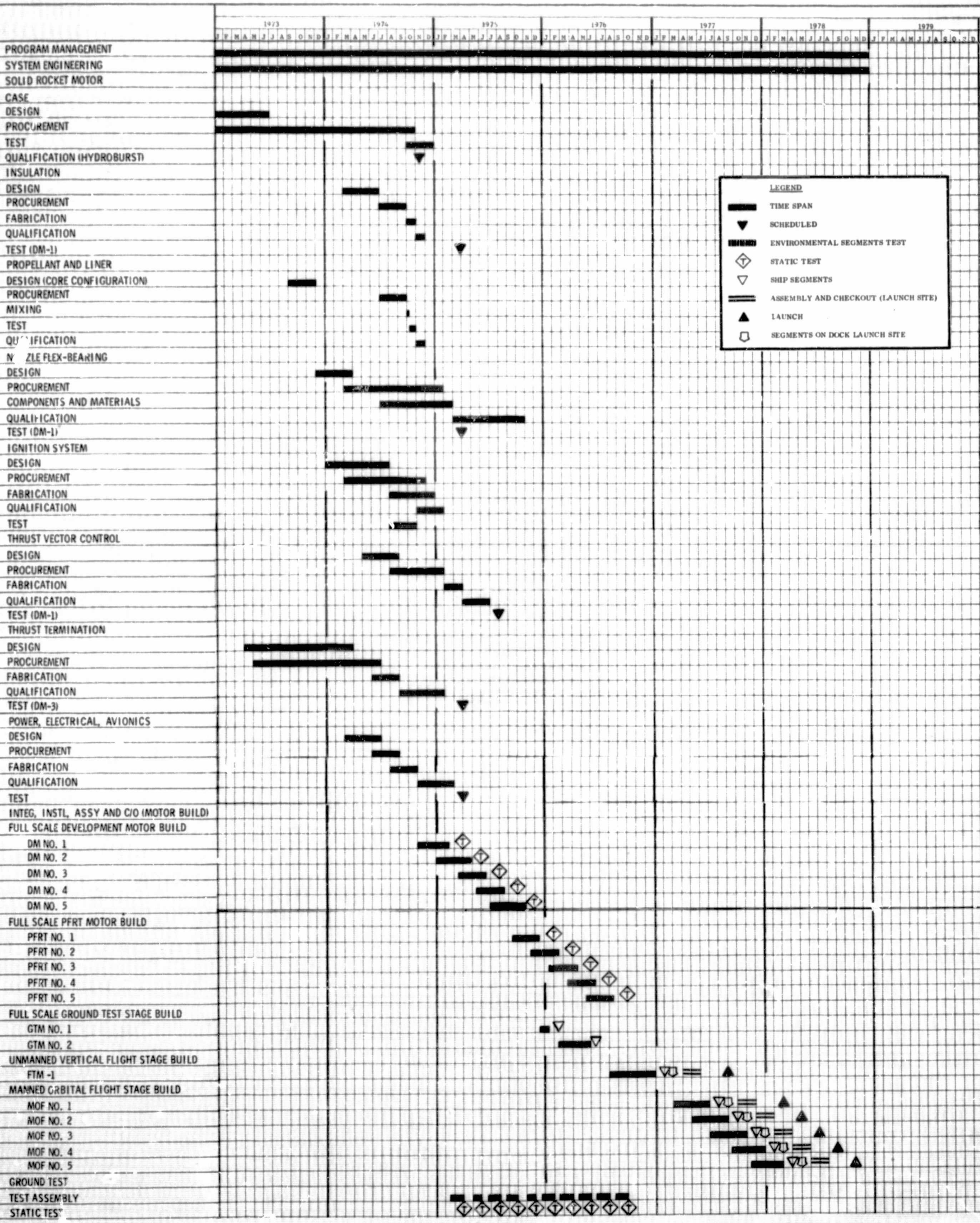
Supplementing these training techniques will be a ground support equipment orientation and familiarization period for personnel who will phase into the program early. Whenever data indicate a deficiency in skill knowledge, retraining or additional training will be conducted.

11.7.2 Certification of Personnel

Manufacturing/processing skill certification constitutes an inherent part of the inplant training program. The operational and maintenance engineering analyses will be analyzed to establish skill requirements. From this analysis special training courses will be developed and presented to the required personnel. Upon completion of these courses, the trainees will be tested to insure their capability in the specialty needs and the results made a part of their training record. Periodic recertification, when considered necessary by Production/Quality Control, will be performed.

Thiokol launch crew certification requirements will be established jointly by Thiokol and NASA. The skills and proficiencies incumbent upon the crew will be organized into a concentrated training course. Certification scope will be established as a Thiokol/NASA agreement. Acceptance of a Thiokol launch crew representative will be subject to such certification.

SPACE SHUTTLE PROGRAM MASTER SCHEDULE (Sheet 1)



SPACE SHUTTLE PROGRAM MASTER SCHEDULE (Sheet 2)

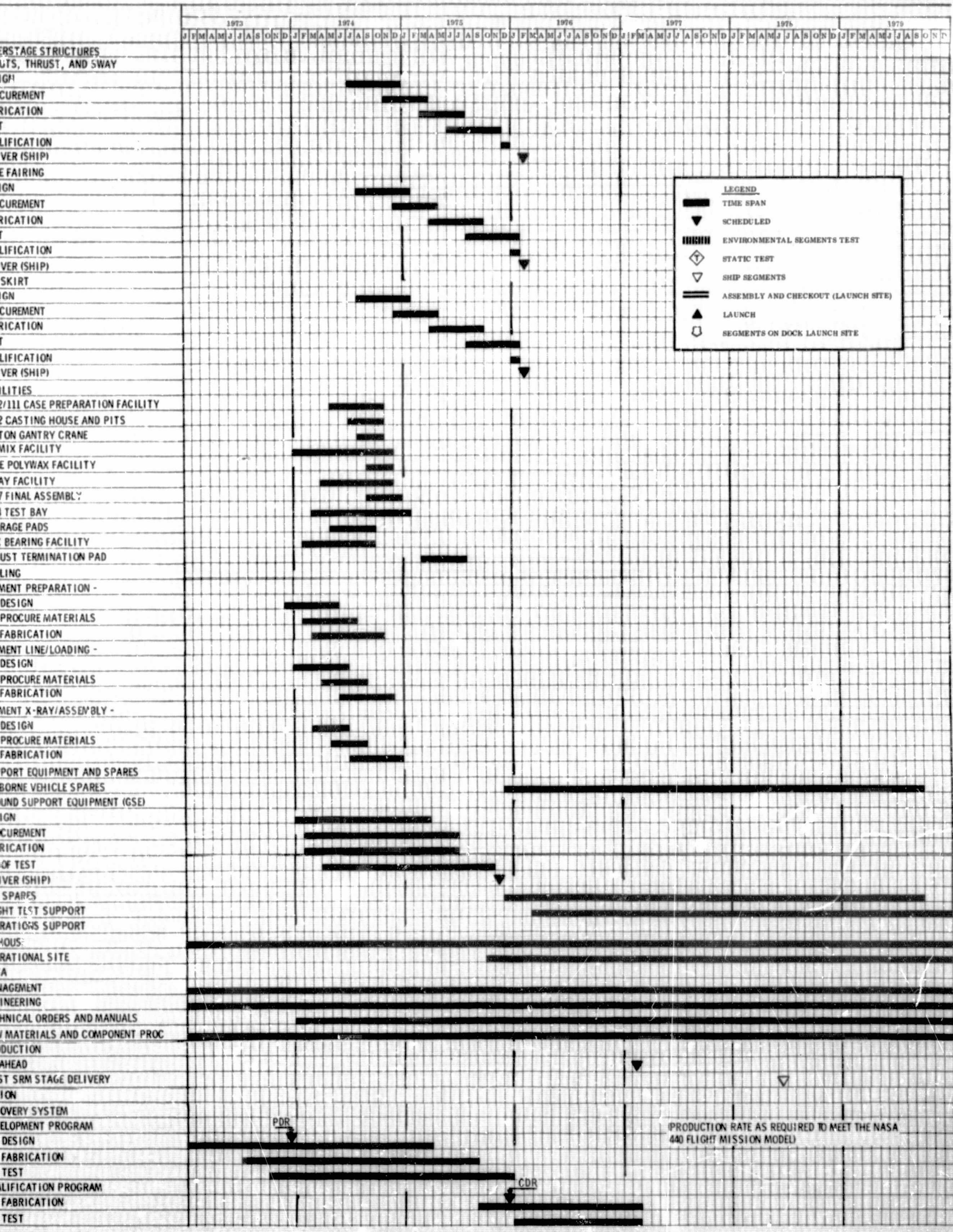


TABLE 2-1. MOTOR TEST MATRIX

MOTOR	TEST OBJECTIVES	TEST COMPONENTS						ENVIRONMENTAL TESTS*			TEST CONDITIONS				INSTRUMENTATION AND DATA CHANNELS									TEST DATE
		IGNITER	CASE	PROPELLANT AND LINER	NOZZLE	FLEX BEARING	FLIGHT TVC	TEMP CYCLE	TRANS AND HAND.	EMI SURVEY	TEST SITE	TEST STAND	THRUST TERM.	QUENCH	THRUST	PRESS.	EVENTS	EXTEN-SOMETER	STRAIN	VIBRATION	ACOUSTIC	TEMP	COMB. PROD.	
DM-1	EVALUATE GRAIN, BALLISTICS, CASE, INSULATION, NOZZLE, AND IGNITION	X	X	X	X	X	X				TCC	MULTI-COMP		X	7	19	58	11	10	15	30	32	30	TIME ZERO
DM-2	EVALUATE GRAIN, BALLISTICS, CASE, INSULATION, NOZZLE, AND IGNITION AFTER BEING TEMPERATURE CYCLED	X	X	X	X	X	X	X			TCC	MULTI-COMP		X	7	19	58	11	10	15	30	32	30	2 MO
DM-3	EVALUATE GRAIN, BALLISTICS, CASE, NOZZLE, INSULATION, IGNITION, THRUST TERMINATION, AND DESTRUCT	X	X	X	X	X	X			X	TCC	SINGLE COMP	X 50% BURN		1	19	58				30	32	30	4 MO
DM-4	EVALUATE GRAIN, BALLISTICS, CASE, INSULATION, NOZZLE, AND IGNITION	X	X	X	X	X	X				TCC	MULTI-COMP		X	7	19	58	11	10	15	30	32	30	6 MO
DM-5	EVALUATE GRAIN, BALLISTICS, CASE, INSULATION, NOZZLE, AND IGNITION AFTER TRANSPORTATION AND HANDLING TESTS	X	X	X	X	X	X		X		TCC	MULTI-COMP		X	7	19	58	11	10	15	30	32	30	8 MO
PFRT 1	VERIFY AND EVALUATE GRAIN, BALLISTICS, CASE, INSULATION, NOZZLE, AND IGNITION	X	X	X	X	X	X				TCC	MULTI-COMP		X	7	19	58	11	10	15	30	32	30	10 MO
PFRT 2	VERIFY AND EVALUATE GRAIN, BALLISTICS, CASE, INSULATION, NOZZLE, AND IGNITION	X	X	X	X	X	X				TCC	MULTI-COMP		X	7	19	58	11	10	15	30	32	30	12 MO
PFRT 3	VERIFY AND EVALUATE GRAIN, BALLISTICS, CASE, INSULATION, NOZZLE, AND IGNITION	X	X	X	X	X	X				TCC	MULTI-COMP		X	7	19	58	11	10	15	30	32	30	14 MO
PFRT 4	VERIFY AND EVALUATE GRAIN, BALLISTICS, CASE, INSULATION, NOZZLE, AND IGNITION	X	X	X	X	X	X				TCC	MULTI-COMP		X	7	19	58	11	10	15	30	32	30	16 MO
PFRT 5	VERIFY AND EVALUATE GRAIN, BALLISTICS, CASE, INSULATION, NOZZLE, AND IGNITION	X	X	X	X	X	X				TCC	MULTI-COMP		X	7	19	58	11	10	15	30	32	30	18 MO

*ENVIRONMENTAL TESTS WILL BE CONDUCTED ON UNASSEMBLED SEGMENTS OF THE MOTOR; ONE SEGMENT EACH OF FORWARD, AFT, AND CENTER